FIRM/C778

ACOUSTIC SYSTEMS FOR THE ASSESSMENT OF FISHERIES

Edited by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, December 1984

PREPARATION OF THIS DOCUMENT

FAO's André Mayer fellowships are intended for research on a subject of interest to FAO. In September 1981, Mr J.D.R. Bayona started such a study of commercially available acoustic equipment for fish stock assessment in developing countries and of the acoustic survey methods applied in various fisheries research institutes. This study resulted in two papers of which the first was presented at the ICES/FAO Symposium on Fisheries Acoustics, held in Bergen, Norway, from 21 to 24 June 1982, as contribution no.116. The second paper was prepared after the Symposium.

At the Symposium, several other papers describing acoustic equipment were presented in Session K., by Mr R.B. Mitson as Rapporteur.

Considering the rapid developments in acoustic survey equipment, it was found opportune to combine the publication of the reports of the André Mayer fellow with some of the relevant Symposium papers and invited papers to cover all known brands of commercially available acoustic equipment for the quantitative assesment of fish stocks. The papers were edited by Mr R.B. Mitson. Thanks are due to Mr J.J. Traynor for corrections and comments on Paper 10. Special thanks are due to all those who have assisted the FAO André Mayer fellow in his research, in particular, the Director and staff of the Institute of Marine Research in Bergen, Norway, where Mr Bayona was based.

Comments are invited and may be directed to the authors, the editor, or Mr S.C. Venema, Marine Resources Service, Fisheries Department, FAO, Rome.

W/R1938

For bibliographic purposes this document should be cited as follows:

Mitson, R.B. (ed.), Acoustic systems for the assessment of fisheries. FAO Fish.Circ., 1984 (778):132 p.

FAO Fisheries Circular (FAO Fish.Circ.)

A vehicle for distribution of short or ephemeral notes, lists, etc., including provisional versions of documents to be issued later in other series.

ABSTRACT

This document contains 11 papers, of which 10 describe and/or compare scientific echo-sounders, echo-integrators for fish stock assessment, and an echo-sounder simulator for acoustic survey design and training. The last paper discusses differences in scaling the results obtained with echo-integrators of several fisheries research institutes.

CONTENTS

	Page
Comparison of Acoustic Survey Systems for use in Developing Countries. John D.R. Bayona	1
Biosonics Model 101 and Model 105 Echo-Sounders. Alan R. Wirtz	21
The Furuno FQ50: An Echo-Sounder for Fish Stock Assessment. T. Sasakura, H. Shiraishi, H. Iino, K. Minohara, H. Aoki	31
Simrad EK400 Scientific Echo-Sounder. R. Brede	44
An Echo-Sounder Simulator for Acoustic Survey Design and Training. A. Borud, T.W. Hansen, S.Ø. Johannessen	57
Dual-Beam Target Strength System. J. Ehrenberg.	71
AGENOR: A Digital Echo-Integration System for Fisheries Research. R. Person, E. Marchal, T. Terre, J. Berthe	81
Biosonics Model 121 Digital Echo-Integrator. Alan R. Wirtz	90
Simrad QD Echo-Integrator. R. Brede	100
Differences in the Scaling of Echo-Integrator Survey Results by Fisheries Research Institutes. John D.R. Bayona	107

COMPARISON OF ACOUSTIC SURVEY SYSTEMS FOR USE IN DEVELOPING COUNTRIES 1/

by

John D. R. Bayona
FAO/André Mayer Research Fellow

1. INTRODUCTION

Acoustic assessment of fish stocks for both exploratory and management purposes is invaluable for enhancing rational resource exploitation and also its utilization in developed and developing countries. However, the implementation calls for high initial capital investment and technical expertise (Thorne, 1980); these pre-requisites constrain the adoption and continuance of such techniques in developing countries.

Whilst the harnessing of marine and freshwater resources can substantially mitigate the increasing problem of food shortages and malnutrition in developing countries (Larsen, 1980), lack of finance and the technological challenges are still serious handicaps. Resource assessment and management programmes in many developing countries have not always worked well partly due to:

i. lack of technicians to reliably maintain and calibrate the equipment
ii. lack of spare-parts as a result of limited purchasing power, restrictions on imports and the related bureaucracy
iii. inadequate foreign currency to purchase the desired equipments from abroad.

These problems can be alleviated by different approaches, including consideration of the equipments most likely to provide successful acoustic surveys in the relevant countries.

It is the purpose of this paper to discuss some results of the current study sponsored by FAO on the suitability of acoustic systems for use in developing countries, by means of a comparison of some of the available systems. In addition to prompting the translation of these countries demands into hardware and software by commercial companies it is envisaged that the study will also benefit fishery biologists worldwide, through the dissemination of information on the systems, their capabilities, and availability. It should be noted that this paper considers some of the latest echo-sounders and automatic signal processors, whereas other integral components of an acoustic assessment system

i. the type and size of vessels to be used
ii. sampling facilities
iii. operating personnel

are disregarded. It is recommended, however, that planners of acoustic surveys in different countries should consider such components separately and try to optimise them for the conditions dictated by the survey design selected; the size of the area to be

1/ This paper is a modification of Contribution No. 116 of the ICES/FAO Symposium on Fisheries Acoustics, June 1982, Bergen, Norway, by the same author entitled "General standards of acoustic assessment systems suitable for use in developing countries.
Present address: Tanzania Fisheries Research Institute, P.O. Box 90, Kigoma (Tanzania).

surveyed and the environmental conditions as well as the type of biological sampling necessary. See, for example, Johannesson and Mitson, 1983.

2. THE CHOICE OF SYSTEMS FOR DEVELOPING COUNTRIES

Three constraints, regardless of their varying degrees of impact to different developing countries, are considered grossly deterministic of the systems to be adopted, these are:

i. the nature of the actual applications of acoustic systems
ii. limited scope of technical expertise
iii. limited purchasing power (finance).

Features which allow versatility are important because, considering the nature of many applications, each one requires different system characteristics for optimum results. In Margetts (1977) there is a good coverage of applications for acoustic systems, for example, surveys of the abundance and distribution of adult or juvenile fish, nekton and zooplankton; monitoring of plumes resulting from dredging and refuse dumping, etc. These are distinct cases which may be further subdivided into freshwater or marine applications, although there are some common characteristics amongst them which can be identified to support a definition of what is a versatile system.

Irrespective of the selected priorities by developing countries, it can be gauged that target size, depth range, and properties of the water medium are the tacit variable characteristics common to all. These are frequency dependent (Forbes and Nakken, 1972; Saville, 1977). Low frequencies promote long range detection because they suffer least attenuation by absorption as opposed to high frequencies. Attenuation is exacerbated in marine waters due to higher salinity and the general hydrological conditions compared to freshwater, especially at depths greater than 100 m where it may lead to errors in fish density estimates (Simmons and Forbes, 1980; Foote, 1981). High frequencies with small wavelengths allow short pulse lengths for better detection close to boundaries, or improve the depth resolution between targets in schools.

The operating frequency of the system is the key upon which all other system parameters may be adjusted for optimization under different applications. Multi-frequency equipment designs which allow selectable frequencies are therefore recommended as a rational adoption by developing countries because of their adaptability to different uses and cost effective designs. Now the current practice of purchasing totally new equipments for any desired changes in frequency, can be replaced by inexpensive designs requiring the replacement of frequency modules and transducers.

Where progress is delayed through limited technical expertise being available, training is indispensable as a means to transfer technological knowledge. The problem can also be alleviated by resorting to the following:

i. simple and easy to use systems
ii. systems able to resist adverse laboratory or field operating conditions, in that their production specifications are stable or repeatably reproducible

iii. systems must be durable but the occasional servicing should be backed by an adequate supply of spare-parts

iv. systems should be kept well calibrated and be simple to recalibrate.

The problems of limited purchasing power should be mitigated by the above conditions, since correctly dimensioned systems should be moderately priced. Likewise, durability implies a cutback on spending for spare-parts and repairs. Further cost saving can be obtained in some circumstances by the use of portable systems whose operation requires only small, inexpensive vessels and cheap sources of driving power.

3. GENERAL FEATURES OF THE LATEST DATA ACQUISITION SYSTEMS

There are several designs of scientific echo-sounders available for fisheries research and management. However, the following considerations only refer to a selection of the latest commercially available echo-sounders, the Simrad EK-400, Simrad EY-M, and BioSonics Model 101. The former two are European and the latter is American. The question is to what extent will the systems suit different users needs , are the needs of developing countries taken into account by commercial producers? Discussion on the superiority of any one system relative to another is beyond the scope of this paper, but pertinent system features are tabulated (Table 1) to compare

i. portability

ii. versatility and cost effectiveness

iii. accuracy and reliability

iv. sophistication and approximate cost.

3.1 Portability

Portable designs confer appreciable advantages over others. Apart from the ease with which systems can be transported from one body of water to another, operational costs can be minimized by their use on small inexpensive vessels, especially if the systems have a low power consumption. Such portable features are among the needs of developing countries, and are well demonstrated in the designs of:

i. The Simrad EY-M. The EY-M system comprises a compact recorder and transceiver weighing 8.6 kg and 14.6 kg when connected to a fin-mounted transducer. It consumes a maximum of 24 W, often car battery operated.

ii. The BioSonics Model 101. The BioSonics 101 has a light-weight transceiver, 12.7 kg in weight, with moderate power consumption (30 W). When coupled with a modified Ross Chart Recorder Model 250 c (9 kg) and a transducer, the system weight is approximately 28 kg, suitable for operation on vessels within a broad range of sizes.

iii. Simrad EK-400. This system is suitable only for installation on big vessels, it weighs approximately 96 kg including a transducer, and its rated power consumption is 425 and 705 W maximum for single and dual modes of frequency operation respectively.

3.2 Versatility and Cost-Effectiveness

The Simrad EY-M design permits freshwater, riverine, and even coastal marine applications (Brede, 1980; Lindem and Nunnallee, 1978). The TVG module is changeable to attain close compensation for the actual absorption losses in freshwater and salt waters. It has a good TVG over a detection range of up to 100 m at the fixed operating frequency of 70 kHz.

An EY-M system can detect fish within a wide range of target strengths based on its linear dynamic range of -50 dB//1V to +9 dB//2V. However, the system is not adaptable over a wide range of uses for which the cost effective problem is raised, especially when considerations are given to uses in developing countries. A good example of the need for a more versatile system is that of Lake Tanganyika. The seasonal high level of fish abundance is synchronous with a large quantity of planktonic jelly fish (Leloup, 1952; Bayona, 1978). Here, studying the effects of such planktonic organisms on estimates of fish abundance should not necessarily dictate the purchase of a new high frequency echo-sounder. The survey can be implemented cost effectively by an echo-sounder which permits selection of operating frequencies and preferably with a dual frequency capability.

The designs of the Simrad EK-400 and the BioSonics Model 101 suit many applications due to their multi-frequency capabilities and a wide range of input parameters for optimization (Table 1). Frequency options are available in the range of 25-550 kHz with additional flexibility in the choice of absorption coefficients for Model 101 echo-sounder (Wirtz (this volume)). Therefore the system is flexible for use in freshwater, riverine, estuarine and marine environments. It should be noted however, that little is known about the scattering effects of fish targets at frequencies other than 30, 38 and 120 kHz; applications in the range 200-250 kHz will require much empirical work.

The Simrad EK-400 allows for the selection of frequencies 12, 18, 27, 38, 49, 120, 200 kHz (Brede, 1980) but with preselected absorption coefficients. There may be a need to change modules to account for absorption coefficients due to different temperatures and salinity. A feature of the system is that it accommodates dual modes of frequency operation without use of external multiplexers. The echo-sounder suits marine applications and can also be used in freshwater. Both BioSonics Model 101 and Simrad EK-400 can be used for *in situ* measurements of target strength as a special application, being generated simultaneously with fish densities, or under dual receiver applications. Unlike the case of the two systems where either dual receivers or the simultaneous operation of TVG functions permits generation of *in situ* estimates of target strength, the EY-M achieves the same in a different manner. The users experience of the system indicate that good estimates of target strength distributions and pertinent target densities can be generated when recordings are made under the 40 logR, TVG function, but a special computer signal processing system is needed (T. Lindem - personal communication).

3.3 Accuracy and Reliability

The accuracy of both relative and absolute estimates of acoustic abundance is directly limited by the accuracy and reliability of the system calibration used (Saville,

1977). Most critical is the field calibration of the electronic and acoustic systems prior to any survey. A well calibrated system requires:

i. accurate TVG so that the received voltages are independent of the range
ii. a monitoring system for any variable gain adjustments
iii. a stable transmit-power output.

Acoustic source level (SL) and receiving sensitivity (SRT) can be obtained separately or as a combined parameter (SL+SRT).

To ensure higher accuracy and stability in the latest systems compared to their predecessors, the design of both BioSonics Model 101 and Simrad EK-400 incorporate a variety of features, e.g. the TVG functions are digitally controlled to ensure an accuracy of ± 0.5 dB at any point in the full depth range; transmitters are transistorized to ensure stability of power output; range timers are crystal oscillator controlled; there are in-built signal generators for calibration and monitoring of system performance. Laboratory tests indicate temperature stabilities of ± 0.5 dB at 0°-55° and ± 0.5 dB at 10°-35°C for the EK-400 and Model 101 respectively (see owner's manuals). Above all, the users experience indicates that the stabilities and the overall performance in respect of EK-400 (O. Nakken, personal communication) and Model 101 (D. Gunderson, personal communication; Carlson et al., 1980) should be ranked as excellent.

Although the Simrad EY-M lacks some of the above stated features, i.e. TVG functions are not digitally controlled and range timers are tacho-generator controlled, yet it is highly stable with adequate accuracy for some fisheries research and management purposes. Overall system drift is less than 1 dB after 10 minutes of warm-up (T. Lindem, personal communication). Temperature stability is ± 1 dB at 0°-55°C with a TVG accuracy of ± 1 dB at full range (Users Manual). From these factors it can be seen that the EY-M is able to generate good data as in the case of the other two systems. However, it should be noted that the accuracy of estimates generated by the three systems can be similar or different, depending on how the sources of bias, other than those of system calibration, are treated or accounted for.

3.4 Sophistication and Cost

From Table 1, the nature and extent of sophistication portrayed by both Simrad EK-400 and BioSonics Model 101 are obvious. The EY-M system is simpler and more moderately priced at U.S.$ 3,609.00 as compared to the Simrad EK-400 and BioSonics Model 101 selling at U.S.$ 18,954.00 and 28,800.00 respectively (see Table 1). Prices quoted exclude the cost of transducers and optional units.

Clearly, the capabilities of the latest designs of echo-sounders to undertake almost all surveys for fisheries management applications accurately are obvious. However, none of the designs actually meets the pre-set standards necessary to promote their successful and sustained use in developing countries. A good choice appears to be the EY-M design which is moderately priced, simple to use, portable, stable and of adequate accuracy, but, it lacks some versatility and the related cost-effectiveness. Thus, the need for firms to design or redesign systems to accommodate the needs of developing countries is obvious.

4. A GENERAL SURVEY OF THE LATEST SIGNAL PROCESSING SYSTEMS

The need for more accurate estimates of fish abundance during the last decade has partly dictated the pace of proliferation and sophistication of signal processing systems and techniques. Originally, fish were estimated by counting marks on echograms corresponding to individual fish, or by judging the overall darkness of echograms (Midttun and Nakken, 1971; Forbes and Nakken, 1972). Manual target counting or amplitude measurements based on oscilloscope (CRT) displays is another technique (Richardson et al., 1959; Truskanov and Scherbino, 1966; Thorne et al., 1972; Nunnallee and Mathisen, 1972b). Automatic signal processing techniques using echo-counters and echo-integrators lent themselves to the purpose with varying degrees of technical sophistication as can be learnt from Mitson and Wood (1961), Carpenter (1967), Dowd (1969), Dragesund and Olsen (1965), Lahore and Lytle (1970) and Thorne (1971, 1977).

Whilst there are various levels of limitation and bias inherent to each of the techniques, greater accuracy, stability and flexibility can be attained by microprocessor or computer based digital echo-integration (Thorne, 1977; Coombs and Francis, 1979; Brede, 1980). The integration technique is optimal under high density situations (Ehrenberg, 1977) whereas echo-counting based on automatic signal processors is expedient under low density situations and fails at high densities. The two techniques can be adapted to suit the needs of developing countries under certain conditions.

4.1 Digital Echo-Integration

Research and management institutions in developing countries, as administered by either individual nations or jointly with the Food and Agriculture Organization of the United Nations (FAO), should benefit from this technique by a prior evaluation of the best mode of application and the availability of suitable equipments.

Two modes of signal processing by digital integration exist, namely:

i. Real time processing of receiver output signals during a survey

ii. later processing of analog signals preserved on magnetic tapes.

Based on the experience gained by many researchers, including Coombs and Francis (1979), subsequent digital processing of analog signals recorded on tape suffers from disadvantages which are summarized as follows:

a. Many analog recorders have restricted dynamic range and bandwidth such that loss of fidelity of the signals may occur, especially if the transmit pulse duration is less than 0.5 ms. Likewise a broad distribution of target sizes hence signal amplitude, will either lead into saturation problems, or force a compromise situation where targets at either the lower or upper extreme are eliminated. A few very expensive recorders can resolve these problems.

b. The playback speed of the recorder governs the rate at which analog signals are digitised, consequently inhibiting the computer processing capabilities and resulting in high labour and computer costs.

c. Estimates are not readily available for 'judging' or decision making as desired by certain research and management regimes.

d. Field performance of the data acquisition systems cannot be evaluated in real time.

In addition to the disadvantages highlighted above, rising labour costs for processing analog tapes further impede the rationale of implementing this mode of data analysis in certain environments. At the University of Oslo where facilities for this type of analysis are available, a one hour cassette of recorded data may be processed for U.S.$ 100 (Lindem, personal communication). Hence, analysis of acoustic data for certain lakes, e.g. Lake Tanganyika whose size and sporadic distributions of fish demand about 80-100 hours of recorded information, will ultimately be very expensive, costing about U.S.$ 10,000 per single survey. The disadvantages discussed above prompt a conclusion that A-D processing of taped signals is not the optimal way of undertaking research and management applications in developing countries, especially with the advent of portable, moderately priced digital echo-integrators for real-time processing.

Of recent equipments for real-time processing, the BioSonics Model 120, French AGENOR and Simrad QD digital integrators are selected to illustrate a broad range of features (Table 2). Respective details are portrayed in papers 7, 8 and 9. Regardless of their varying levels of sophistication all are programmed to conduct the routine integration at appreciable levels of accuracy (Brede, 1980; Wirtz, 1984; Person et al., 1984). Both Simrad QD and BioSonics Model 120 are commercially available with an adequate supply of spare-parts and are selling at U.S.$25,000 and U.S.$20,000 respectively. The French AGENOR is currently at U.S.$13,000, but it will probably be selling at nearer the current price of BioSonics Model 120 after final improvements as a commercial product. Nevertheless, by close evaluation of the system features (Table 2) while taking into account the basic demands for developing countries it is obvious that with current technology, simple yet high quality digital echo-integrators can be, or are already developed within a cost range of U.S.$12,000-18,000.

The BioSonics Model 120 is a good example based on,

i. high dynamic range, 72 dB
ii. 30 depth channels for integration
iii. light weight (12 kg) and highly portable
iv. low power consumption, 90 W
v. automatic micro-processor based control systems.

Firms can build even cheaper systems to suit the needs of research and management institutions in developing countries if there are good communication links with well co-ordinated programs.

4.2 Echo-Counting

The application of echo-counting techniques by means of automatic signal processors can be relatively cheaper than echo-integration. However, the type of environment in which the techniques can be used are fairly limited, based on the conditions to be met. These require:

i. Low fish density situations so that individual targets can be resolved (Ehrenberg, 1973 in Margetts, 1977)

ii. The echo-sounder should at the best be operated at high transmit power with short pulse duration to provide good resolution (Dowd, 1969; Kalikhman et al., 1979)

iii. Fairly calm weather conditions are vital to minimize the input of noise to the system and the related serious limitations to the accuracy of the counts (Mitson & Wood, 1961; Ehrenberg, 1977).

A counting technique can be applied for riverine applications, especially in the assessment of fish runs up or down stream. Under the stated circumstances, developing countries could consider the use of counting systems which may cost U.S.$10,000 to 15,000. An example of a commercially available system for echo-counting is BioSonics Model 200 Digital Echo Counter, selling at U.S.$15,000.[1/]

5. DISCUSSION

There are problems of limited expertise in technology and of purchasing power in the successful adoption of modern acoustic assessment systems by different fisheries research and management regimes, particularly in developing countries. These problems can be partly alleviated by resorting to the use of simple and portable, yet high quality and versatile, moderately priced systems.

The Simrad EY-M is a good example of a data acquisition system possessing the desired standards for users in developing countries. However, the design requires some changes to attain the necessary versatility, a feature which the manufacturers should consider vital in the current or next generation of equipment. Above all, the need for real-time processing of acoustic data is emphasized based on the commercial availability of simple, portable and moderately priced digital echo-integrators, for example the BioSonics Model 120 Digital Echo-Integrator.

It should be borne in mind that reliable acoustic abundance estimates can only be obtained when a certain amount of biological information on the scatterers is available. During all acoustic surveys there will be a need for knowing what is being recorded, and hence representative samples of the recorded organisms should be at hand. The costs involved in meeting this requirement will in most cases exceed the cost of purchasing and operating any acoustic system. Thus because the capture and accurate identification of the scatterers is of vital importance to the results of any survey, these matters should be considered with care when planning acoustic survey work.

It is recommended that Fisheries Research and Management Institutes in developing countries should exercise their role to furnish information relating to specific research problems to affect significantly the commercial development of desired equipments. The need for a well established communication link between such users (Research and Management Institutes in developing countries) and commercial firms or producers is considered vital under the umbrella of UN/FAO.

1/ Price of 1982.

Table 1. Features of the latest generation of echo-sounders

Features	Echo-sounders		
	BioSonics Model 101	Simrad EK-400	Simrad EY-M
1. Portability			
(i) composite units of reference	Model 101 Transceiver	AR 800 Recorder MV 101 Control Unit and a Transceiver	Compact Recorder and Transceiver Units
(ii) System weight	12.7 kg	90 kg	8.6 kg
(iii) Power Consumption	30 W, or 80 W when coupled with a chart recorder (Ross 260 C) 115 VAC/240 VAC	705 W for dual frequency 425 W for single frequency	24 W 12-15.6 VDC
	Note: When used with Ross 250 C - Recorder 9 kg and a transducer (≈ 6 kg) the system weight is about 27.7 kg. Portable and suitable for small and big vessels.	When used with a transducer (≈ 6 kg) the system weight is approximately 96 kg. Suitable for non-portable uses and installation on big vessels.	When used with a towed fin transducer the system weight is approximately 14.6 kg. Portable and suitable for small vessel operations.
2. Versatility			
(i) a. Operating frequency	Selectable: 25-550 kHz	Selectable: 12, 18, 27, 38, 49, 120 and 200 kHz	70 kHz
b. Dual frequency applications	No	Yes	No
(ii) a. TVG	Digitally controlled with ± 0.5 dB accuracy (38 kHz)	Digitally controlled with ± 0.5 dB accuracy (38 kHz)	Analog with ± 1 dB accuracy
b. Dual TVG function operations	Yes (by additional circuit board)	Yes	No
c. Selectable absorption coefficients (without change of modules)	Yes	No	No

Table 1. (contd)

Features	Echo-sounders		
	BioSonics Model 101	Simrad EK-400	Simrad EY-M
d. Dynamic range of TVG amplifier	140 dB (in a bandwidth of 0.33 kHz)	140 dB (in a bandwidth of 0.33 kHz)	120 dB (in a bandwidth of 1 kHz)
e. Maximum Receiver gain	20-150 dB depending upon range, and $2\alpha R$ setting	85 dB (to calibrated output - 38 kHz)	85 dB (to calibrated output)
(iii) Overall system dynamic range	73 dB	70 dB	59 dB
	Highly versatile due to multi-frequency capability. Selectability of absorption coefficients	Versatile due to multi-frequency capability	Not versatile
3. Range of Parameters and Selectability			
(i) Control	Control parameters are selected by switches or knobs	Parameters input from keyboard	Knob or switch selection of control parameters
(ii) Transmit Circuitry			
a. Design	transistorized	transistorized	transistorized
b. Standard power	0.05-1 kW, selectable in 5 steps of approximately 3 dB increments	2.5 kW, with four possible selections at 250 W, 600 W, 1250 W and 2500 W	.075-0.1 kW
		HIGH (full power) or LOW (1/10 or full power) selections are also available	
c. Power boost	Up to 10 kW maximum depending on operating frequency	Up to 8 kW maximum, depending on operating frequency	Up to 1.1 kW

Table 1. (contd)

Features	Echo-sounders		
	BioSonics Model 101	Simrad EK-400	Simrad EY-M
iii) Transmit pulse	- triggered internally, or externally - pulse duration adjustable from 0.1-9.9 ms at 0.1 steps	- triggered internally or externally - pulse duration selectable for every operating frequency (1.0, 3.0, 10 and 30 ms for 12 and 18 kHz; 0.3, 1.0, 3.0 and 10 ms for 27, 38 and 49 kHz; 0.1, 0.3, 1.0 and 3 ms for 120 and 200 kHz)	triggered internally or externally fixed pulse duration, 0.6 ms
iv) Receiver bandwidth	Selectable between 1, 2, 5 and 10 kHz	Selectable between 0.1, 0.33, 1.0, 3.3 and 10 kHz	fixed at 2.2 kHz
v) Depth range	- Max range depends on recorder options	Maximum recorder range is 17000 m (phased at 12-18 kHz) 3400 m (phased at 27-200 kHz)	Maximum recorder range is 360 m (phased)
	- TVG range is variable depending on the operating frequency	TVG range is variable with frequency selected	3-100 m at fixed frequency of 70 kHz
vi) Receiver output	Available as: a 'RF' output b 8 kHz for tape recording c Detected, lowpass filtered signal d Bottom detect output e Trigger/Sync. pulse (A broad range of parameters for optimization exists)	Available as: a 'RF' output b 12 kHz for tape recording c Bottom detect output d Trigger pulse (A broad range of parameters for optimization exists)	Available as: a 'RF' output b 10 kHz for tape recording c Trigger pulse (Limited range of parameters, but are optimum for the operating frequency)

Table 1. (contd)

Features	Echo-sounders		
	BioSonics Model 101	Simrad EK-400	Simrad EY-M
4. Optional Capabilities			
(i) Can utilize a broad range of recorders	Yes	Yes	Yes
(ii) Depth scale expansion	Will depend on recorder options	Possible to expand the depth scales: 2.5, 5, 10, 25, 50, 100 and 250 metres over the full width of the recording paper	Not possible
(iii) Display converter capabilities	Not available	Available (integration limits and values can be portrayed on chart recorder)	Not available
(iv) Inbuilt signal conditioning electronics (precision detector)	Yes	Yes	No
(v) Use of any desired integrator	Yes	Yes	Yes, a QI interface unit is needed
(vi) Mode of recorder paper logging	Manual or automatic depending on the selected recorder	Automatic	Manual
5. Accuracy and Stability (i) Design features:	a. Digitally controlled TVG functions ensuring accuracy of ± 0.5 dB over 110 dB range	a. Digitally controlled TVG functions ensuring accuracy of ± 0.5 dB at any point	a. Non-digital control but ensuring accuracy of ± 1 dB

Table 1. (contd)

Features	Echo-sounders		
	BioSonics Model 101	Simrad EK-400	Simrad EY-M
	b. Transistorized transmitter ensuring power output stability of ± 0.5 dB at 10°-35°C c. Range timers are crystal oscillator controlled ensuring ± 0.05% accuracy d. In-built calibration circuitry with continuous wave (CW) or Pulsed operation modes for calibration and monitor of receiver gain	b. Transistorized transmitter ensuring power output stability of ± 0.5 dB at 10°-55°C c. Range timers are crystal oscillator controlled ensuring ± 0.005% accuracy d. In-built test generator for easy checking of the sounders performance	b. Transistorized transmitter for power stability of ± 0.2 dB at 0°-55°C c. Range tacho-generator controlled ensuring ± 1% accuracy d. In-built test oscillator for calibration and checking of the receiver gain
(ii) Laboratory tests	Temperature stability is + 0.5 dB from 10°-35°C	Temperature stability is + 0.5 dB at 0°-55°C	Temperature stability is ± 1 dB at 0°-55°C
(iii) Users experience	Drifts are in the range of ± 0.5 dB (personal comm. Dr E. Nunnallee, NMFS - Seattle, U.S.A.)	Drifts are in the range of ± 0.5 dB (personal communication H. P. Knudsen - Inst. Mar. Res. Bergen)	Drifts less than 1 dB after 10 minutes (personal communication Dr T. Lindem, University of Oslo)
6. Costs of the System Prices Sept. 1984 FOB origin	(i) Model 101 Echo-Sounder (Transceiver US$ 25,800 - Model 250 C Russ Recorder US$ 3,000 28,800	(i) EK-400 Unit (Transceiver, Control Unit, and Recorder) NOK 164 900 US$ 18,954	(i) EY-M Compact Unit (Transceiver and Recorder) NOK 31 400 US$ 3,609 1/
	(ii) 38 kHz transducer US$ 6,000 (20° full beam) US$ 34,800	(ii) 38 kHz transducer US$ 2,874 (8 by 8) NOK 25 000 or (8 by 22) (US$ 1,563) NOK 13 600 US$ 21,828	(ii) 70 kHz Transducer (11°) NOK 8 650 US$ 994 US$ 4,603

1/ Exchange rate 1 US$ = 8.7 NOK (Sept. 1984)

Table 2. Features of the three latest digital echo-integrators

Features or capabilities	Digital Echo-Integrators		
	Simrad QD	BioSonics Model 120	French AGENOR
1. Circuitry Units and Functions	Comprises 5 units: i) Simrad QX (selection of input signal, envelope detection, 12 bit analog — digital conversion, signal squaring and interfacing to high speed computer) ii) DIM 1035-High speed computer; (squared echo levels are transferred to data memory every dm, control of sequencing, interrupts, and transfer of raw data to general computer) iii) DIM 1003 General computer: (deals with all computations or refinement of results) iv) DIM 1016-16 k data memory (for storage) v) QD-Interface Unit (Analog/ Digital conversion of vessel speed log pulses, supply of layer marker pulses to the recorder	Comprises 4 units: i) Central Processing Unit (control file, decodes all information in the ROM and issue appropriate commands to other hardware devices) ii) Analog —Digital converter (12 bit conversion of analog to digital units) iii) System bus (100 wires for communication with other units) iv) Interface Unit (hardware interface to enable CPU send instructions to peripheral devices e.g. Clock for A-D Converter, Recorder interface, front panel interfaces - thermal printer, alphanumeric display key-board, alarm etc)	Comprises 3 units: i) Signal conditioning electronics (input Amplifier, Detector and Analog —Digital Converter) ii) CPU-1: General computer (data acquisition and system control e.g. automatic bottom tracking, display and keyboard control) iii) CPU-2 Floating Point computer (for computations and output control e.g. integrations scaled by number of pings, samples above threshold, correction constants and printing of results)
2. System Control	- microcomputer control system - commands logged from external printer	- microprocessor based control system with a keyboard for selection of parameters, a display panel and internal printer	- microprocessor based control system with a keyboard for selection of parameters, a display panel and internal printer

Table 2. (contd)

Features or capabilities	Digital Echo-Integrators		
	Simrad QD	BioSonics Model 120	French AGENOR
3. Modes of data processing	i) Ordinary integration ii) Integration by sequencing (alternate pings at different frequencies) iii) Data logging	i) Ordinary integration ii) Data logging	i) Ordinary integration ii) Data logging
4. Peripheral devices	Printer Analogue recording device Computer interface for signal processing or preservation	Computer interface for signal processing or data preservation	Analog recorder Computer interface for signal processing or data processing
5. Weight and power consumption	25.8 kg Approx. 150 W (230/115 VAC)	12 kg (excluding peripheral units) Approx. 90 W (115/220 VAC)	25 kg (excluding peripheral units) Approx. 140 W (230/115 VAC)
6. Signal selection	Any of 4 coupled echo-sounders	Any of 2 coupled echo-sounders	1 coupled echo-sounder
7. Input signal amplification	None	None (signal conditioning electronics external)	20 dB gain amplifier extra amplification circuitry of -6 to 9 dB at 3 dB steps
8. Signal carrier frequency	10-200 kHz	No limitations	10-60 kHz
9. Dynamic range	70 dB (Signals of 0.0047 Vp-14.2 Vp handled without saturation)	72 dB (Signals of 0.0025 Vp-10.24 Vp are within the limits of A-D converter)	60 dB (Signals of 0.005 Vp-5 Vp are handled without saturation)

Table 2. (contd)

Features or capabilities	Digital Echo-Integrators		
	Simrad QD	BioSonics Model 120	French AGENOR
10. Analogue-Digital circuitry	12 bit A-D Converter Sampling frequency 30 kHz or 33 µs (2.5 cm)	12 bit A-D Converter Sampling frequency 7.5 kHz or .133 ms (10 cm)	12 bit A-D Converter Sampling frequency 7.5 kHz or .133 ms (10 cm)
11. Sample resolutions	2.5 cm	1 dm or 10 cm	1 dm or 10 cm
12. Digital threshold	available up to 880 mV different thresholds can be used for different depth channels	available up to 999 mV one threshold value is applicable to all depth channels	available up to four digits in mV one value is applicable to all depth channels
13. Squaring circuitry	Hardware and real time squaring circuitry	Hardware and real time squaring circuitry	logical selection from input tables of 1000 possible finite values
14. Bottom tracking	A bottom window parameter is available to avoid integration of false bottom pulses the printer will print <<< marks and integration will be up to the maximum specified range Bottom offset value is available (0-1 m) to avoid integration of bottom	A bottom window is available to avoid integration of false bottom pulses Alarm will come on for missing bottom pulses and wrong window settings Bottom offset value of 1 m is available to avoid integration of bottom	A bottom window is available to avoid integration of false bottom Alarm will come on for missing bottom pulses and wrong window settings Bottom offset value is available in dm
15. Layer-picture	10 integration channels (8 surface and 2 bottom locked) max. integration depth is 1000 m	30 integration channels (surface or bottom locked modes) maximum integration depth is 1000 m	12 integration channels (10 surface and 2 bottom locked) maximum integration depth is 500 m

Table 2. (contd)

Features or capabilities	Digital Echo-Integrators		
	Simrad QD	BioSonics Model 120	French AGENOR
16. Correction for TVG anomalies	Not available	Available by input B values, one for each channel (B is a scaling factor related to propagation losses at the operating frequency)	Available by input B values, one for each channel
17. Output analog signal	Available for school size studies	Not available	Available for school studies
18. Output format	Single table: mean volume back scattering strength (Sv) and mm deflection values are given for each corresponding depth channel, data is given for each log sequence	Single table: average integrated values proportional to fish density are given for corresponding depth channels in addition to % integration data is given under file number, output sequence and number of pings	Three tables for every log output per corresponding depth channel, integrated voltages/values scaled by pings, total samples and samples above threshold. Each output indicates date, time, sequence no. and number of pings
19. Value or cost of units	QD with Silent 703 data terminal NKr 216 700 (US$ 25,000) 1/ Optional sequencing proms NKr 25 000 (US$ 2,900)	Price for Model 121, upgrade of Model 120 (US$ 24,600) 2/ Optional spare cards for Model 121 (US$ 10,200)	Complete unit - (US$ 12,000) 3/ Printer - Analog (US$ 1,000)

1/ Prices FOB Horten. Sept. 1984. 1 US$ = 8.7 Nkr

2/ Prices FOB Seattle Sept. 1984

3/ Prices of 1982

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APPENDIX I

A NOTE ON THE IMPROVEMENTS TO THE QM Mk II ECHO-INTEGRATOR

INTRODUCTION

Simrad QM Mk II Echo-integrators are now out of commercial production. However, many institutes are already in possession of these equipments and are in favour of using them to undertake some of the acoustic survey applications. Under such circumstances, the need to improve the QM performance and eliminate some of its limitations is obvious. This note cites the work done to improve the system performance. Many QM echo-integrators in various parts of the world have been modified to the specification set by the Fisheries Laboratory, Lowestoft, England.

Low cost improvements of the QM echo-integrator were made as follows:

i) The detector module was replaced to enhance the system dynamic range from approximately 43 dB to 65 dB. This allows higher gain settings to be used.

ii) All thumbwheel switches were changed to eliminate the possibility of gate opening in the wrong place.

iii) A saturation warning circuit was added to give warning of 'integral sounding' overload. This includes a buzzer for an audible warning of saturation.

iv) Various resistors and operational amplifiers were changed to improve temperature performance and to simplify setting up and calibration.

v) Threshold potentiometer was replaced by a switch to make settings more definite and repeatable.

vi) Earth wiring was altered to remove power supply ripple from signals.

vii) Counters were added to count number of 'Integral Nautical Mile' resets.

viii) A switch to allow a fixed manual speed setting was added.

Improvements Under FAO Sponsored Projects

An interface for the EY-M echo-sounder and the QM echo-integrator has been published as FAO Fisheries Circular 754.

A Playback Interface Unit was fitted into the QM echo-integrator to allow the processing of tape recorded signals (analog), from the Simrad EY-M echo-sounder. The interface receives the control waveform from the tape recorder left channel and separates it into transmission trigger and bottom pulses. The level of a trigger pulse is increased from 7 volts to a range between 12-15 volts and it is set at a higher duration of 4 ms compared to the original pulse duration of 0.6 ms. Bottom pulses are set to a duration of 6 ms at a voltage level of 12-15 V.

Whilst the EY-M sounder does not provide a bottom detect output, a Recording Interface was developed and fitted into the echo-sounder to eliminate the problem. The interface combines the transmission trigger pulse and the bottom echo pulse to form a composite control waveform which is then recorded on the left channel of the tape.

The above modifications allow for either real time analog integration of signals directly from the EY-M sounder or later processing by analog to analog (A-A) integration of tape preserved signals.

BIOSONICS MODEL 101 AND MODEL 105 ECHO-SOUNDERS

by

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1. INTRODUCTION

Echo-sounder systems can be technologically simple or sophisticated depending on the quality of data required. For simply locating the bottom or determining the presence or absence of fish, the systems marketed to commercial fishermen are quite adequate. However, these cannot provide the accuracy, stability and flexibility needed for scientific research and/or fisheries management. BioSonics echo-sounders, and other acoustic instruments, are designed specifically for collecting acoustic data for scientific purposes under a wide range of conditions. The quality of an acoustic survey of fish is highly dependent on the echo-sounder which produces the primary output signal for recording or further data processing.

2. THE MODEL 101 ECHO-SOUNDER

The functional description that follows is for the Model 101, although much of it is also applicable to the Model 105 which is discussed in Section 4. If readers find this description lacking in the detailed technical information they desire additional information can be obtained from BioSonics. Figures 1 and 2 show the appearance and operator controls of the Models 101 and 105 respectively.

2.1 Frequency

Model 101 echo-sounder is configured for either low frequency (25 kHz-150 kHz) or high frequency (200 kHz-500 kHz) operation. Within these limits, the system frequency can be changed by simply replacing a few circuit modules, crystals, and the transducer. Low frequency echo-sounders are converted to the high frequency version (or vice versa) by changing the power amplifier, which, together with the other components is easily changed in the field.

2.2 Transmitter

Triggering of the transmitter can be by an external signal or by the internal trigger generator. Separation between pings is selectable from 0.1 s (10 pings/s) to 99.9 s in 0.1 s steps (see Figure 1). A pulse-duration timer gates the transmitter ON for an interval from 0.1 ms to 9.9 ms in 0.1 ms steps. The peak output power for the low frequency version of the Model 101 is selectable from 50 to 1000 watts in five steps (the maximum average power output is 25 W). Maximum output power for the high-frequency version is 400 watts with five selectable power settings and the transmitter power level is very stable, varying less than ± 0.5 dB. A synchronising output pulse is provided, coincident with the end of the transmit pulse.

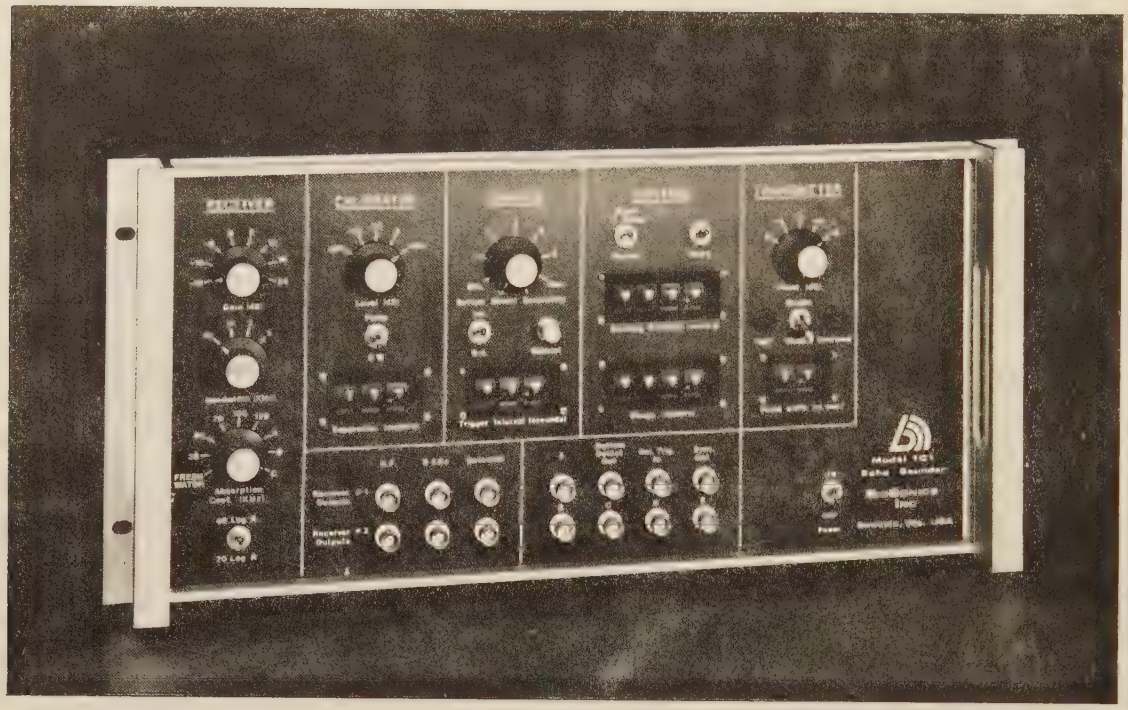


Figure 1. BioSonics Model 101 echo-sounder.

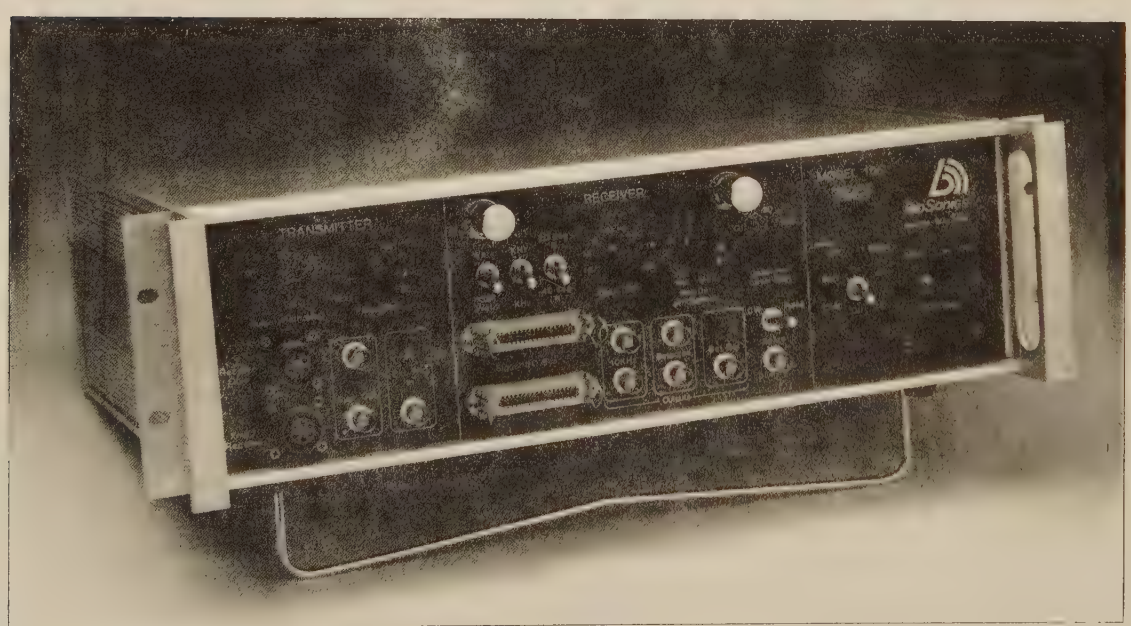


Figure 2. BioSonics Model 105 echo-sounder.

(For both of these models all functions excepting the Bottom Detect Threshold potentiometer are selectable in discrete steps by switches. This assures repeatable accuracy of control settings)

2.3 Transducer

The transducer of an active acoustic system is a critical component. Features to consider when selecting a system transducer are frequency (to match the echo-sounder), power capability, beam angles, sidelobe characteristics, size and shape, and backward radiation. Applications such as dual beam, split beam and very wide angles require special transducers. The method of deployment is also an important consideration (e.g. towed-body or hull mounted). BioSonics, Inc. manufactures a wide variety of transducers with characteristics optimized for a particular application.

2.4 Receiver

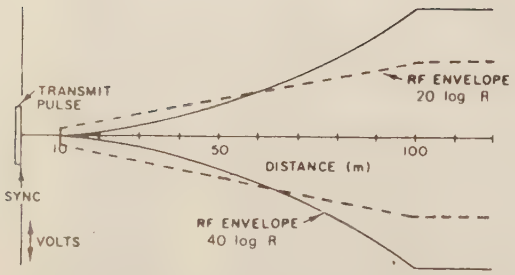
The receiver has to transform the echo signals from the transducer to a level and a form most suitable for display, recording, or signal processing. This would be a relatively simple task except for the very wide dynamic range of signal amplitudes that an echo-sounder must process. Range to the target, absorption, variation in target size, and beam-pattern effects can cause the input signals to the receiver to vary over a range of 10 million to one (140 dB).

A pre-amplifier which has an internal preset gain to match the sensitivity of different transducers forms the first stage of the Model 101 receiver. It is designed to provide stable signal amplification without either overloading on strong signals or degrading the signal-to-noise ratio when very small signals are present.

The pre-amplified signal is then processed by the time-varied-gain (TVG) amplifier which compensates for the loss of signal strength due to spreading and absorption. This is an important part of a scientific echo-sounder. Models 101 and 105 include both a 40 logR TVG and a 20 logR TVG (Figure 3). The latter is used with echo-integration techniques for estimating total fish biomass or the densities of other distributed acoustic scatterers such as suspended particulates or zooplankton. Time-Varied-Gain also corrects for two-way absorption losses which are proportional to $2\alpha R$ decibels. Six different absorption coefficient (α) settings can be selected via a front panel switch with the option of adding three additional settings, which can be configured by the user. The Model 101 TVG amplifiers, including the $2\alpha R$ compensation, are accurate to within ± 0.5 dB over two decades of distance which can be configured internally by the user, or by the makers. Selections available include: 1.25 to 125 m; 2.5 to 250 m; 3.75 to 375 m; 5 to 500 m; and others up to 12.5 to 1250 m.

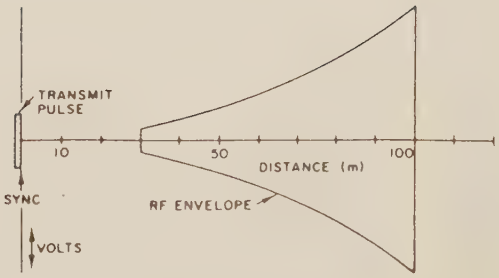
Perhaps the most significant feature of these echo-sounders is the extremely wide dynamic range of the TVG. The equivalent dynamic range of a TVG amplifier is defined as the ratio of the largest signal that it can accept without compression at minimum gain, to the input self-noise at maximum gain in a specified bandwidth. For the Model 101, this voltage ratio is 20 million to 1 or 146 dB in a 1 kHz bandwidth (143 dB in a 2 kHz bandwidth), the largest equivalent dynamic range available in a scientific echo-sounder. This means that the user can make observations over the widest possible range of distances, knowing that the echo-sounder output gives a true representation of the targets of interest. Small targets at long distance can be detected with the least possible interference from the self-noise of the receiver. At the same time, large targets can be

Figure 3.



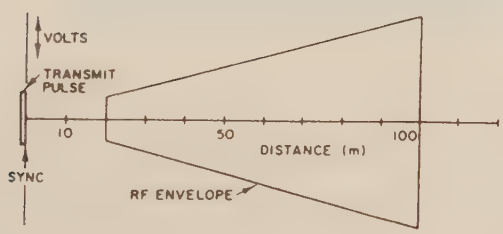
Receiver 8 kHz output with a CW input from the internal calibrator showing TVG operative from 10-100 m

Figure 4.



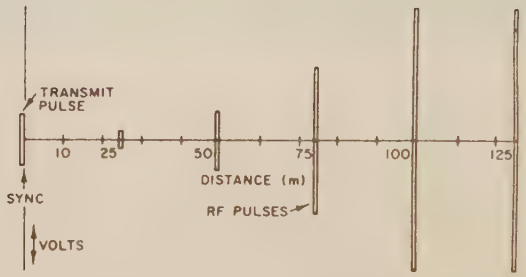
As Fig. 3 but 40 logR only, initial blanking distance extended to 30 m.

Figure 5.



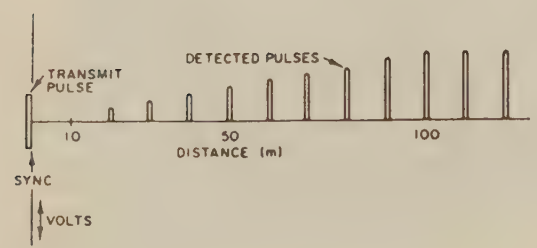
Receiver 8 kHz output for 20 logR with 20 m blanking distance and blank at range = 100 m. CW input.

Figure 6.



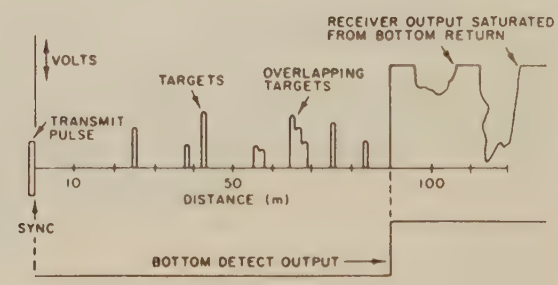
Receiver 8 kHz output for 40 logR with 25 m blanking distance. Pulses from internal calibrator.

Figure 7.



Detected output for 20 logR with 15 m blanking distance. Pulses from internal calibrator.

Figure 8.



Detected output for 40 logR with 10 m blanking distance and range set to 200 m. Normal signals. Calibrator off.

observed close up without distortion due to their signals overloading the receiver.

Further control over the active range of the receiver is by the blanking and range switches. First the blanking switch sets the distance at which the receiver first becomes active (Figures 4 and 5), thus preventing surface clutter and transducer ringing to appear in the output signal. Next, the range switches select the distance at which the receiver TVG action stops (see Figures 3 and 4). The range function is very useful for making receiver measurements at different distances under static conditions, as opposed to the rapidly changing conditions of the TVG. A blank-at-range setting allows the operator to blank the receiver (output = 0) when the set distance is reached (Figures 4 and 5); a useful feature if the observation range needs to be limited.

Receiver gain may be selected over a 42 dB range in 6 dB steps. This allows the user considerable latitude in selecting the gain most appropriate to the target sizes of interest.

Model 101 has a switchable bandpass filter of 10, 5, 2 and 1 kHz to reduce unwanted noise.

In this receiver the echo-sounder frequency is changed to 8 kHz, thus allowing direct analog recording of the output signal. The echo-sounder detected output is from the 8 kHz signal which is very accurate over a 50 dB range of signal amplitudes (Figure 7 and 8). It can be fed directly to a signal processor, such as the Model 121 Digital Echo Integrator or the Dual-Beam Processor.

There is also a bottom-detection circuit and its output which is controlled via a potentiometer on the front panel (Figures 1 and 8). The bottom detect output signal can be fed to other instruments which are processing the Model 101 primary output. For example, the Model 121 Digital Echo Integrator can be programmed to stop integration just before receiving an external bottom detect signal.

2.5 Calibrator

A built-in calibrator when activated, injects a stable signal immediately before the TVG amplifier. This signal is very useful for verifying the receiver stability and the accuracy of the TVG, (Figures 3-7). It is also a convenient reference signal in applications where the echo-sounder output is recorded on tape. The signal amplitude is selectable with 20 dB between the four steps. Either a continuous wave (CW) (Figures 3 and 5) or a pulse signal (Figures 6 and 7) can be used. In use the pulse duration is set by the transmitter pulse-duration switch (0.1 to 9.9 ms) and the separation between pulses may also be selected from 0.1 m to 99.9 m in precise steps of 0.1 m. The flexibility and stability of this calibrator is of great assistance in most acoustic survey or system measurements.

3. OPTIONAL FEATURES AND CUSTOM OPTIONS

The features discussed thus far are all standard, but the Model 101 can be expanded in many ways which implies it should have a long useful life.

One normal option provides simultaneous 20 logR + 2αR and 40 logR + 2αR receiver outputs, useful for applications requiring simultaneous echo-integration at 20 logR and

for echo-counting at 40 logR.

Dual receivers can also be provided. A second independent receiver channel will complete the echo-sounder portion of a dual-beam target strength measurements system. This technique is a valuable and proven way to measure directly the acoustic target strength of individual objects.

Despite the dual receiver configuration with simultaneous 20 logR TVG, there are open slots for three more circuit cards in the Model 101. Practically any special need of the user can be accommodated in this extra space. Some examples of custom circuitry installed in the Model 101 are:

i. increased transmitter power output;
ii. a chart recorder interface;
iii. simultaneous receiver outputs at two different gains;
iv. low level receiver outputs for driving external power amplifiers;
v. an internal transducer multiplexer for alternately pinging on two different transducers;
vi. a ten times pulse duration expansion;
vii. miscellaneous circuit modifications to make the 101 compatible with the use of existing equipment.

4. MODEL 105 ECHO-SOUNDER

The Model 105 Echo-Sounder is smaller, more portable, and less expensive than the Model 101. Although less expansion is possible it is still an instrument of scientific quality. Most of the important features of the Model 101 have been retained, including the same TVG circuits, making this an ideal echo-sounder for applications requiring portability and/or lower cost without loss of scientific precision.

Power can be supplied by AC line voltage or an external 12V battery. All connectors, controls and switches are mounted on the front panel to allow operation in a field enclosure without access to the back. Panel lights are included for night surveys.

The Model 105 can be configured for frequencies ranging from 50 kHz to 500 kHz. A significant feature of this instrument is the capability of dual-frequency operation via simple front panel switch selection, but the two frequencies must be within a factor of four of each other. Possible frequency combinations include 50 kHz and 200 kHz or 120 kHz and 420 kHz.

Many of the Model 101 functions controlled from the front panel are available internally in the Model 105, including blanking and range functions, TVG start distance, transmit power, and $2\alpha R$ compensation. Thus, the Model 105 front panel is less cluttered, and the instrument is easier to operate.

A large number of interconnecting cables between instruments can become unwieldy and confusing. A signal I.O bus has been included on the front panel of the Model 105 to provide convenient, mass interconnections between other acoustic instruments and recording devices. All commonly used input and output signals are present on this bus.

Normal options for the 105 include a second frequency, dual-receivers and simultaneous 20 and 40 logR TVG outputs. Custom modifications or options are available as with all BioSonics instruments.

5. APPLICATIONS

For Lake or Reservoir Surveys BioSonics echo-sounders and other acoustic instruments are sufficiently portable to be routinely used in mobile surveys. One or two persons and a small boat are all that are required, Fig. 9. A simple system consists of a towed body/transducer system, echo-sounder, chart recorder and signal recording system to allow further analysis in the laboratory. A more advanced survey system includes simultaneous integration and dual-beam target strength analysis.

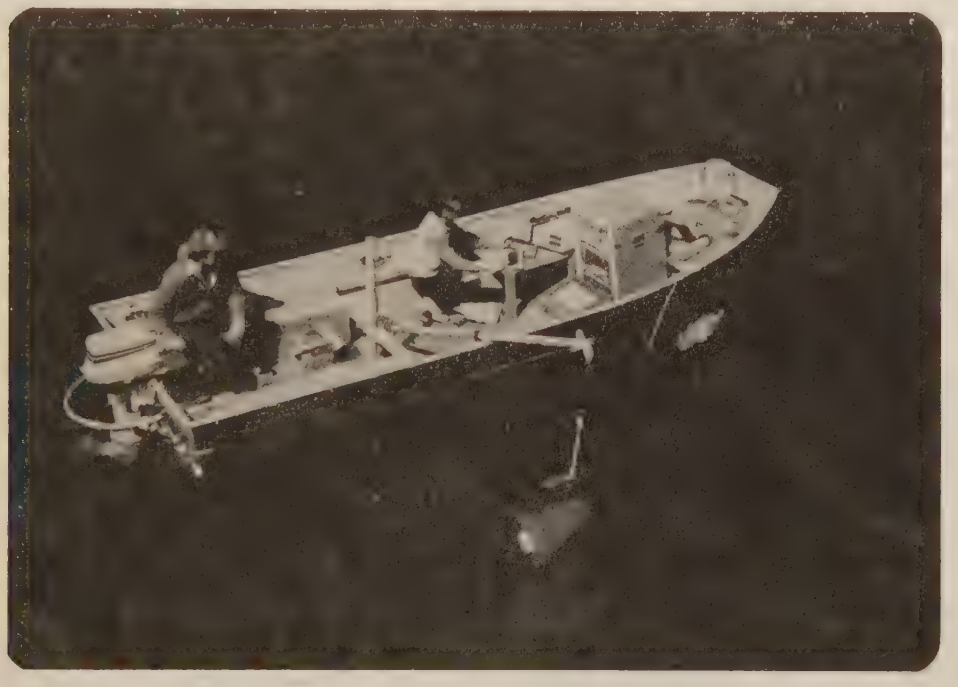


Figure 9. Complete acoustic system on board a small boat.

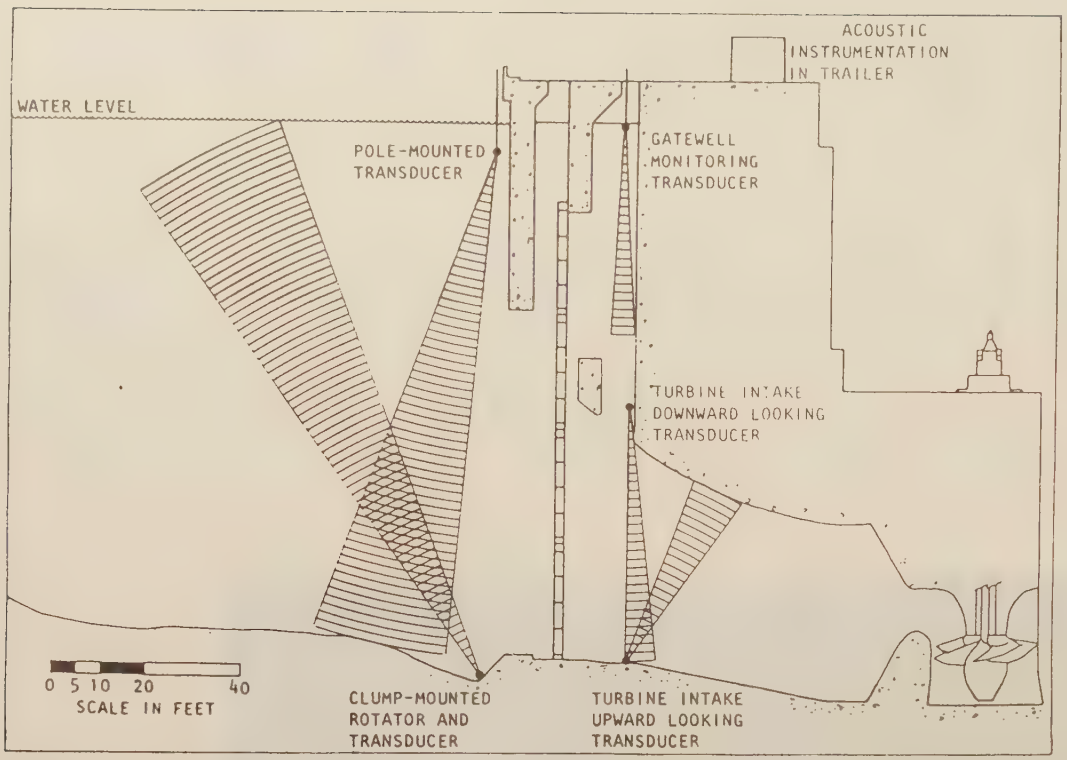


Figure 10. Fixed Location Counting and Fish Behaviour Studies: The BioSonics echo-sounders and other instruments are well suited to fixed location counting and behaviour studies. Four important developments have resulted in a significant advance in fixed location acoustic capabilities. The Model 151 Multiplexer/Equalizer allows a single echo-sounder to be automatically redirected at up to 16 different transducers. Some transducers have been developed with virtually no sidelobes for more efficient monitoring in confined regions such as intake galleries. The dual- or single-axis underwater rotator allows remote aiming of an underwater transducer with accuracy. For situations of high fish density, such as gatewells, the Model 121 Digital Echo-Integrator, in conjunction with the echo-sounder, can provide biomass estimates.

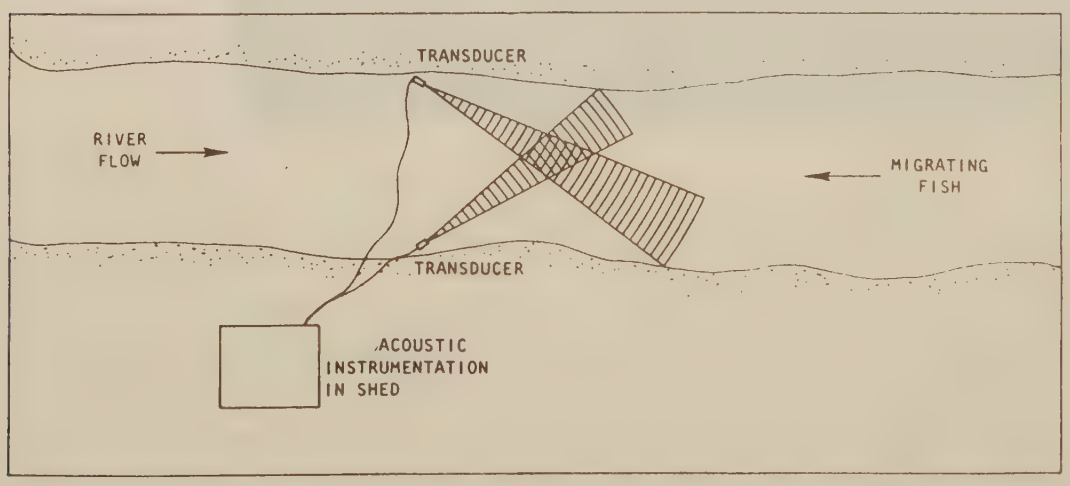


Figure 11. Doppler Counting Migrating Fish: Counting migrating fish in shallow river environments has been beyond the capabilities of conventional acoustic techniques. A Model 101 or 105 coupled to a Model 151 Multiplexer/Equalizer and a BioSonics Doppler Processor is able to count migrating fish accurately. The Doppler Processor uses advanced signal processing techniques to provide fish count information that has, until now, been impossible.

6. TABLE OF SPECIFICATIONS

	Model 101	Model 105
TRANSMITTER		
Frequency	30 to 150 kHz or 200 to 500 kHz	50 to 500 kHz
Frequency Change	Replace 3 filter modules and two crystals (field changeable)	Either of two frequencies via panel switch
Peak Power Output	1000 watts (30 to 150 kHz) 400 watts (200 to 500 kHz)	100 watts
Average Power Output	25 watts	10 watts
Power Levels	0, -3, -6, -10 and -13 dB (relative)	one level only
Load Impedance	50 Ω real	50 Ω real
Stability	±0.5 dB	±0.5 dB
Pulse Duration	0.1 to 9.9 ms in 0.1 ms steps	0.2, 0.4, 0.8 and 1.6 ms
RECEIVER		
Noise Figure	3 dB	3 dB
TVG		
40 log R	80 dB range total (two decades of distance)	80 dB range total (two decades of distance)
20 log R	40 dB range total (two decades of distance)	40 dB range total (two decades of distance)
Starting TVG Distances	1.25, 2.5, 3.75, 5, 6.25... up to 12.5 metres	0.5, 1, 2 and 4 metres
Accuracy (including the $2\alpha R$ term)	±0.5 dB	±0.5 dB
Stability	±0.5 dB	±0.5 dB
Equivalent Dynamic Range (1 kHz Bandwidth)	146 dB	146 dB
Bandwidth	1, 2, 5 and 10 kHz	2.5 and 10 kHz (automatically selected with pulse duration)
Gain	-18 dB to +24 dB (relative) in 6 dB steps	-18 to +24 dB (relative) in 6 dB steps
Absorption Coefficient	Eight different values, plus $2\alpha R = 0$ may be selected by the user	Fresh water ($2\alpha R = 0$) and saltwater (user selected value)
Outputs	RF, 8 kHz and Detected/ Filtered, Bottom Detect	10 kHz and Detected/ Filtered, Bottom Detect

TRIGGER		
External	positive-going trigger signal, 2 V to 100 V	positive-going trigger signal 2 V to 100 V
Internal	ping interval 0.1 s to 99.9 s in 0.1 s steps	8 ping rates from 30/s to 0.2/s
CONTROL		
Blanking Distance	0.1 to 999.9 metres in 0.1 metre steps	Internally configurable 0 to 50 metres
Range Distance	0.1 to 999.9 metres in 0.1 metres steps	Internally configurable 0 to 400 metres
Blank at Range/Normal	Panel Switch	Internally configurable
CALIBRATOR		
Level	-40, -20, 0 and +20 dB (relative)	-40, -20, 0 and +20 dB (relative)
Pulse/CW	panel switch	panel switch
Separation between pulses	0.1 to 99.9 metres in 0.1 metre steps	1.25, 2.5, 5, 10, 20, 40, 80, or 160 metres (internally configurable)
Stability	±0.2 dB	±0.2 dB
POWER		
A.C.	115 VAC or 220-240 VAC 50 or 60 Hz, 30 watts (typical)	115 VAC or 220-240 VAC 50 to 60 Hz, 20 watts (typical)
D.C.	optional	12 V, 17 watts (typical)
SIZE		
Outside Dimensions	230 x 430 x 405 mm deep (not including rack mount handles) (9 x 17 x 16 inches deep)	133 x 430 x 330 mm deep (not including rack mount handles) (5.25 x 17 x 13 inches deep)
Weight	12.7 kg (28 lb)	7 kg (15.5 lb)
OPTIONS		
Additional Frequencies	as many as desired	one additional frequency
Simultaneous 20 log R	yes	yes
2nd Receiver (dual-receivers)	yes	yes
Spare Circuit Cards	yes	yes
Higher Power Transmitter	yes	yes

THE FURUNO FQ 50

AN ECHO SOUNDER FOR FISH STOCK ASSESSMENT 1/

by

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1. INTRODUCTION

There are several different methods of acoustic measurement. FURUNO has developed a scientific echo-sounder system which includes echo-integration, Lahore and Lytle (1970), the method based on volume reverberation theory.

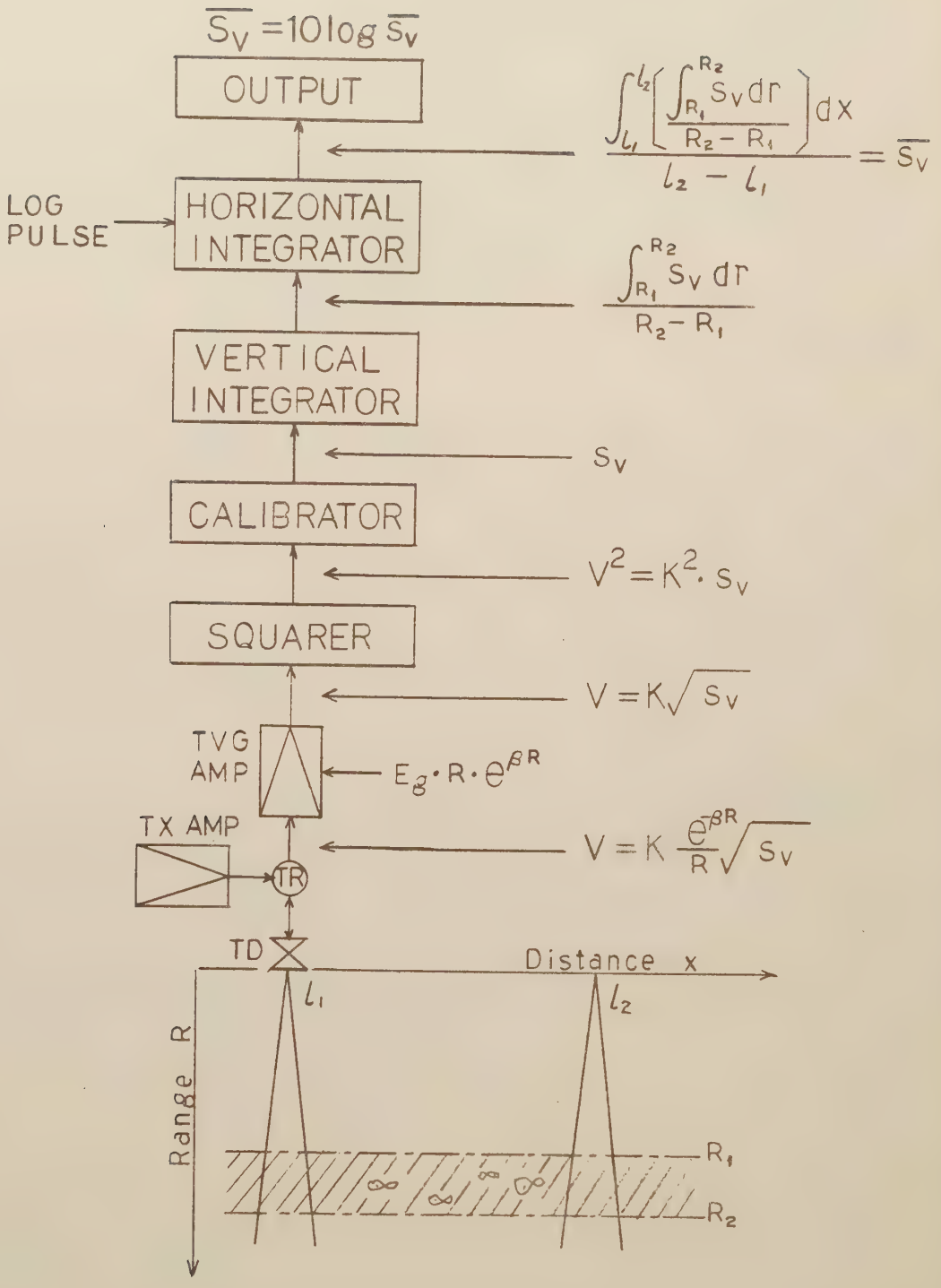
The FURUNO FQ scientific echo-sounder calculates mean backscattering strength in layers at specified depths and log intervals. Results are listed digitally on the data printer but are also drawn on the echogram as vertical distribution curves (VDC). For the convenience of later analysis, navigational data such as ship's position, speed, course, etc. can also be printed out by interfacing appropriate navigational aids.

2. FURUNO FQ SYSTEM

2.1 System Outline

Figure 1 shows a block diagram of the echo integration system. First, the received echo is compensated for transmission loss by the Time Varied Gain (TVG) amplifier. The result is then squared and multiplied by a constant to obtain an instantaneous value of volume backscattering strength (sv). It is then integrated by the Vertical and Horizontal Integrators and finally converted into the expression SV = 10 log sv (dB).

1/ This paper is a modification of Contribution No. 27 to the ICES/FAO Symposium on Fisheries Acoustics, June 1982, Bergen, Norway, by the same authors, entitled: "Echo sounder for fish stock assessment".



Block diagram of the echo-integration system

Figure 1 Block diagram of the echo-sounder and echo-integration system

The FQ system gives a quantitative treatment to the received echo information through calibration of electrical and acoustical parameters specific to the system.

Two causes of transmission and echo attentuation, i.e. the spreading loss (20 log R or 40 log R) and that due to absorption ($e^{-\beta r}$), are compensated by the multiplier circuit in the TVG amplifier and the microcomputer respectively. The acoustic parameters of the system are calibrated periodically using a wide-band hydrophone.

Data from the calibrated system are processed by the microcomputer and registered on the recorder and dot printer. On the recorder chart SV values for one transmission-locked and one bottom-locked layer are shown and the dot printer gives integration results for eight transmission-locked and two bottom-locked layers. Integration layers are set independently on the recorder and dot printer, thus 12 different layers can be set at any time. Navigational data can be printed if the appropriate Navaid is connected. All the printout data can be perforated on a paper tape to facilitate later analysis.

2.2 System Configuration

Figure 2 illustrates the system configuration of the FURUNO Scientific Sounder FQ-50. It consists of four major parts: (1) echo-sounder, (2) integrator, (3) data recorder and (4) printer.

The echo-sounder transmits acoustic waves at two frequencies into the sea and receives echoes reflected by objects therein. Echo signals of each frequency go through the correct TVG amplifier and the A/D converter before being stored in the input memory. Data in the memory are then recorded on the paper via CPU1, and at the same time sent to the integrator, which integrates echo signals of the selected depth layers over a preset log interval of distance. The integrated result (SV) is printed while it is also fed back to the echo-sounder to draw vertical distribution curves (VDC) on the recording paper. CPU2 integrates and also compensates for individual parameters such as source level, receiving sensitivity, equivalent beam width, absorption loss, pulse duration, etc. Information from the electronic navigational aids i.e. vessel position, water temperature, vessel speed etc is presented by CPU3 which then enables the print-out. For the convenience of later analysis the dot printer outputs the following parameters.

Volume backscattering strength SV (Depth layers 1 to 10)
and at the end of each log interval
Ship position
Water depth
Water temperature
Ship's speed
Ship's heading.

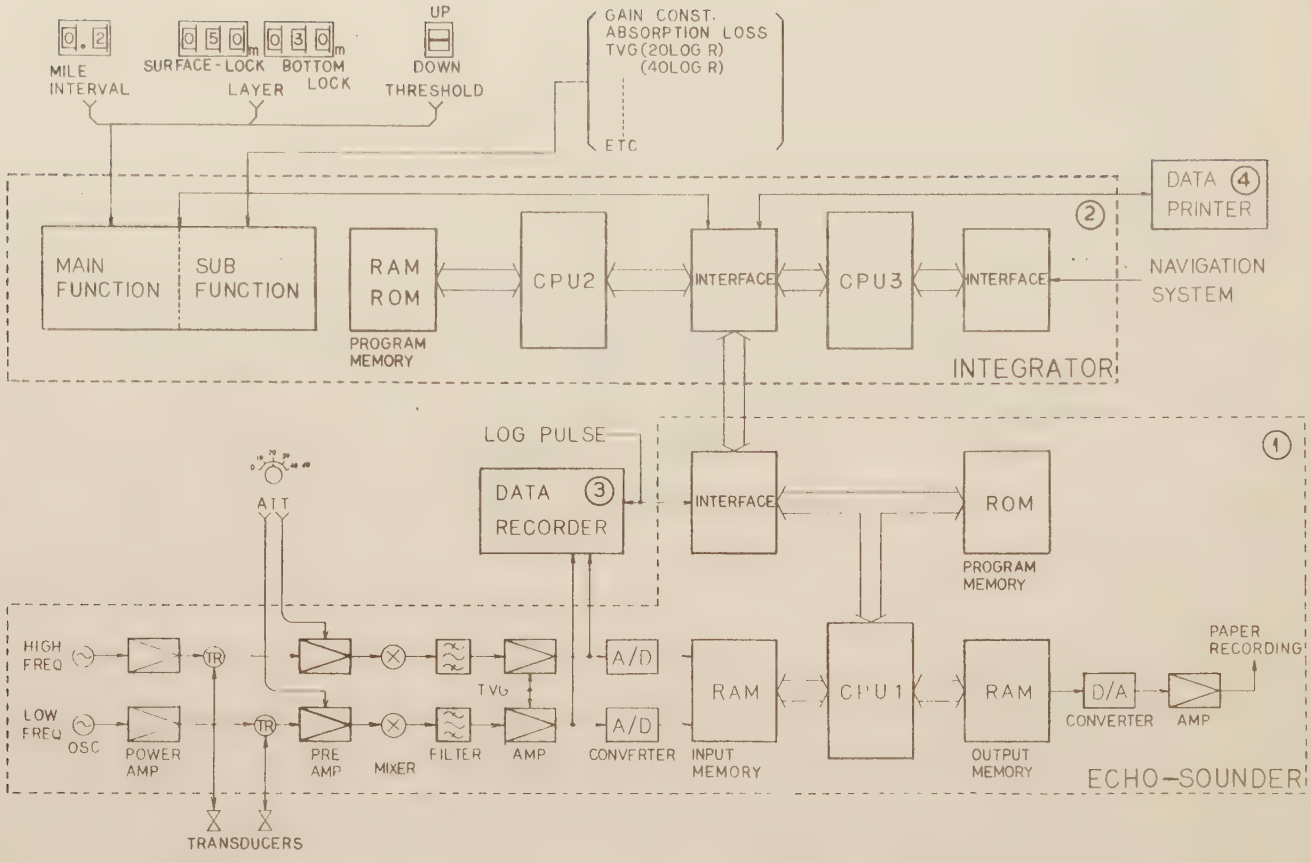


Figure 2 System Diagram

2.3 System Parameters

(1) TVG Function

Figure 3 shows the TVG curves. The 20 logR curve is accurately calibrated to a range of 320 m by an electrical circuit, and compensated for at longer range by the CPU. The 40 logR curve is also controlled to a 100 m range by an electrical circuit, and arithmetically compensated for at longer range by the CPU. Attenuation due to absorption $e^{-\beta r}$ varies with frequency. The CPU automatically compensates for this attenuation when the absorption coefficient (dB/km) of the frequency in use is set on the integrator. The following formula of Murphy et al. (1958) is used for absorption loss compensation:

$$\alpha = 43.5\ f^2\ (7000 + f^2)^{-1} + 33 \times 10^{-5}\ f^2 \quad \text{dB/km} \qquad \ldots\ldots\ldots\ldots\ (1)$$

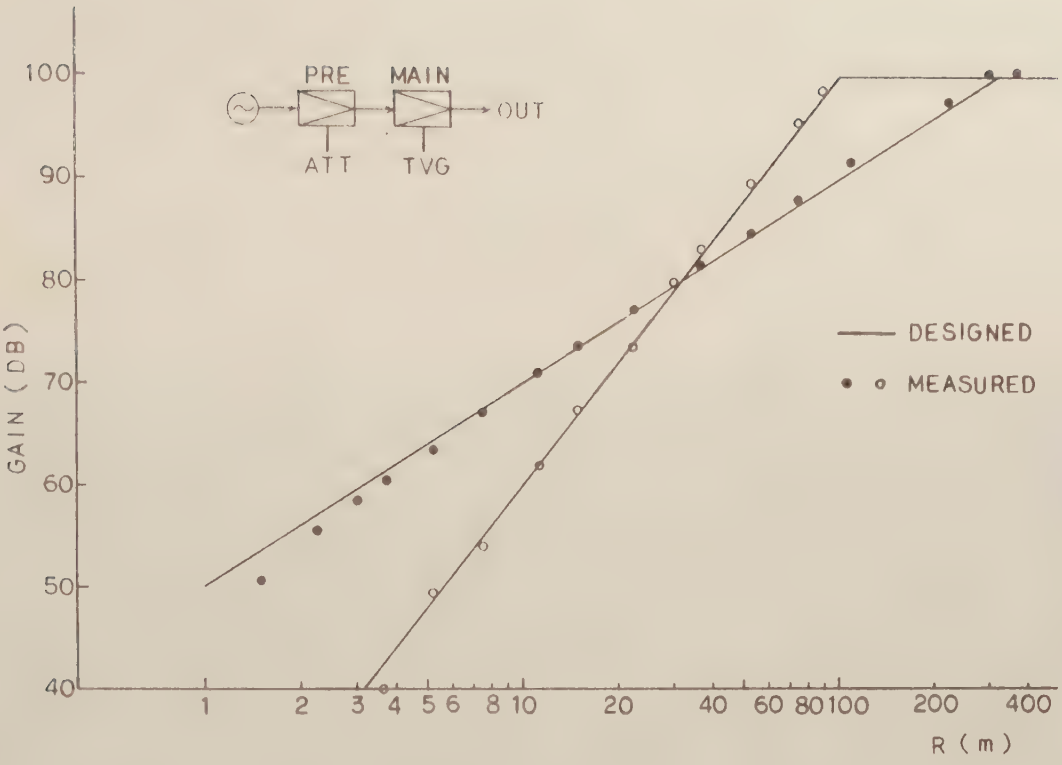


Figure 3 TVG Curves

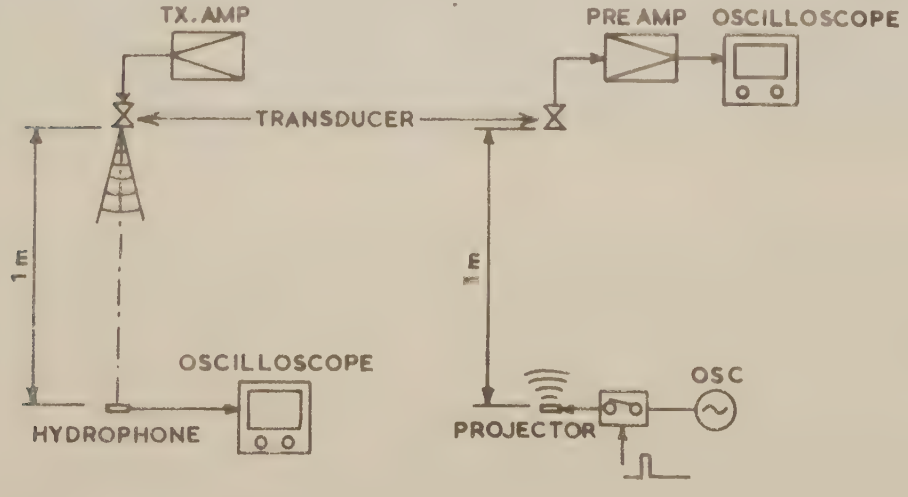
(2) Acoustic parameters

The acoustic parameters necessary to determine sv values are measured by the use of a hydrophone and are set on the integrator. These parameters are calibrated by determining the source level (SL) and the receiving voltage response (SRT) with the hydrophone located 1 m away from the transducer, as shown in Figure 4.

The FURUNO FQ System has approximately the following characteristics:

Source level SL : 220 dB//1μPa/1m

Receiving sensitivity SRT : -180 dB//1V/1μPa



a) measurement of source level (SL) b) measurement of receiving sensitivity (SRT)

Figure 4 Measurement of SL and SRT

The other acoustic parameters (absorption coefficient and equivalent beam width) vary with frequency. The following values apply to the different transducers:

Table 1 Transducer parameters

Frequency (XDR type)	Absorption Loss Coefficient (dB/km)	Equivalent Beam Angle (sterad.)
50 kHz (50F-38)	12.3	0.011 -19.6 dB
88 kHz (88B-10)	25.4	0.019 -17.2 dB
200 kHz (200B-8)	50.4	0.007 -21.5 dB

(3) Data Sampling Rate

The echo is sampled 1024 times over the selected recording range. This means that the echo data are sampled at short intervals on short ranges and at long intervals on long ranges.

Example:

Recording Range	Sampling Rate (= Recording Range/1024)
10 m	0.98 cm
100 m	9.8 cm
500 m	49 cm

2.4 Vertical Distribution Curve (VDC) and Backscattering Strength

A unique feature of the FURUNO FQ System is the vertical distribution of mean volume backscattering strength registered as VDC graphs on the recorder chart at each log interval. An example is given in Figure 5 where VDC graphs are plotted at regular intervals on the normal echogram. These graphs realistically represent the distribution of marine life at different depths. Presented in decibels the VDC graph covers a wide dynamic range of 50 dB.

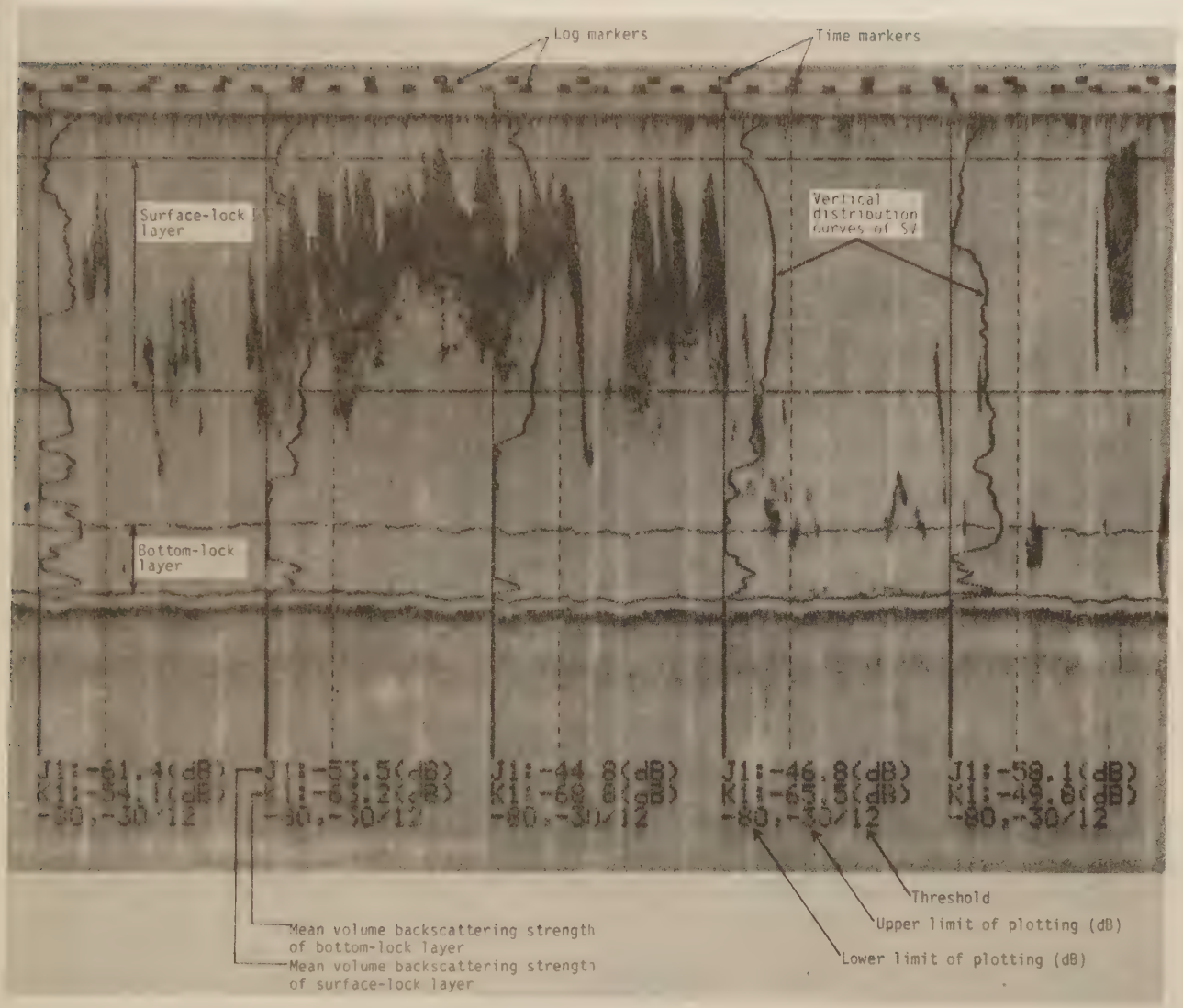
2.5 Calculation of Aggregation Density

In a fishery resources survey, researchers occasionally need to measure the density of particular biomass aggregations besides the average value within the research area. In the FQ system the following two methods are available for measurements of aggregation density:

(1) To measure from the VDC graph and also the dimensions of the fish school on the recording paper. In Figure 6(a) read out the mean volume backscattering strength SV(R) at depth R(m) from the VDC graph then multiply the ratio of the horizontal fish school extension $\ell G(R)$ to log interval ℓ.

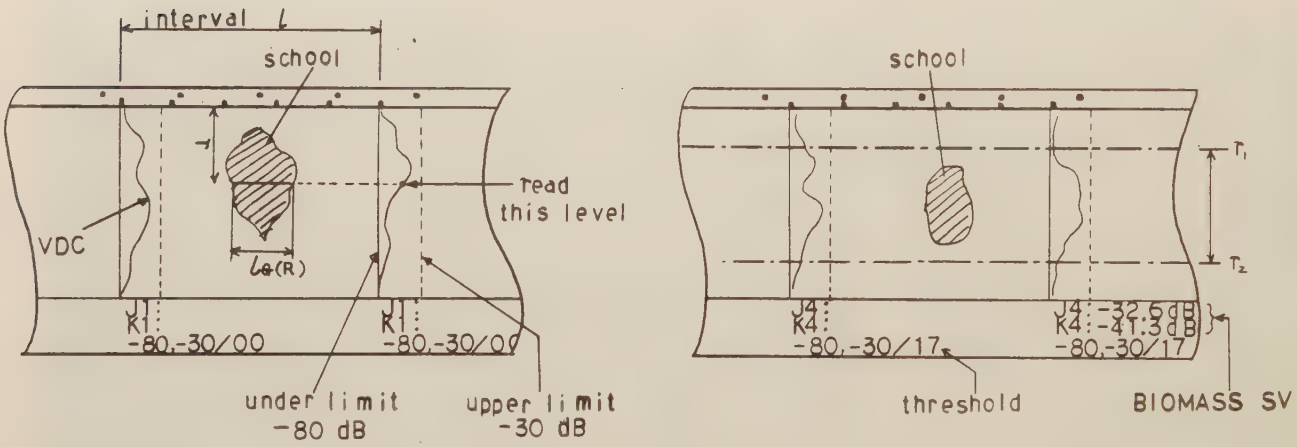
$$\text{BIOMASS } SV(R) = SV(R) + 10 \log \frac{\ell}{\ell G(R)} \qquad \ldots\ldots\ldots\ldots (2)$$

Figure 5. Sample Echo-gram



(2) To select the Aggregation Average Mode. In Figure 6(b) a proper signal threshold is set so that the microcomputer calculates cross-sectional area, SA of the fish school within the integration later (R_1 - R_2). Using these data, biomass backscattering strengths (J4 and K4) are computed.

$$\text{BIOMASS SV} = \text{SV} + 10 \log \frac{\ell\ (R_2 - R_1)}{\text{SA}} \qquad \ldots\ldots\ldots\ldots\ (3)$$



(a) method (1)

(b) method (2)

Figure 6 Methods of Aggregation Density Measurement

3. MEASUREMENTS BY THE FQ SYSTEM

3.1 Target Strength of Krill

Figure 7 shows the relation between target strength and weight of krill measured by the FQ scientific echo-sounder. This measurement showed that a single krill of 1 gram has a target strength of -59.38 dB.

Target strength of krill weighing W(g) becomes

$$\text{TS} = -59.38 + 6.70 \log W \qquad \ldots\ldots\ldots\ldots\ (4)$$

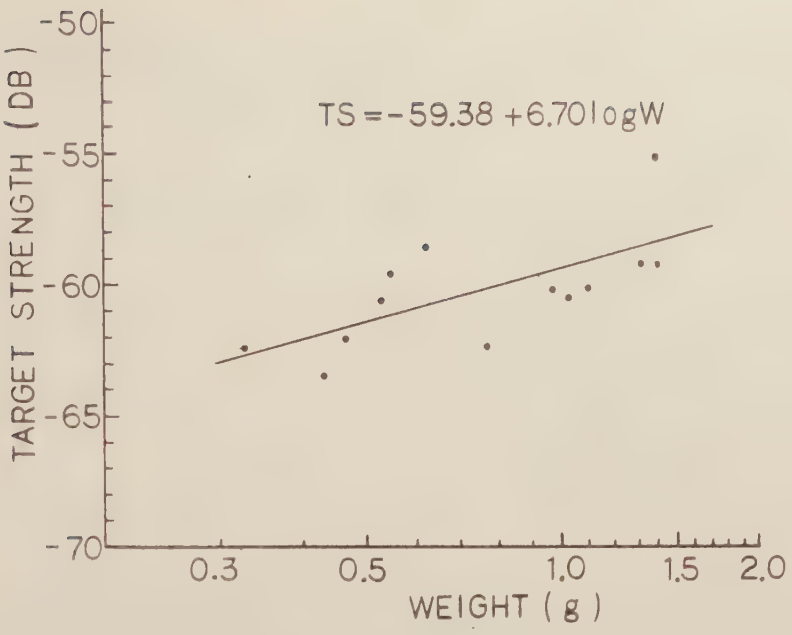


Figure 7 Target Strength of Individual Krill

3.2 Distribution of Krill

Distribution of backscattering strength within the survey areas established in the Antarctic Ocean is indicated in Figure 8. There was not a significant difference between the survey areas A and B. Both areas were almost covered with pack ice, however, the measured SV indicated very high concentrations.

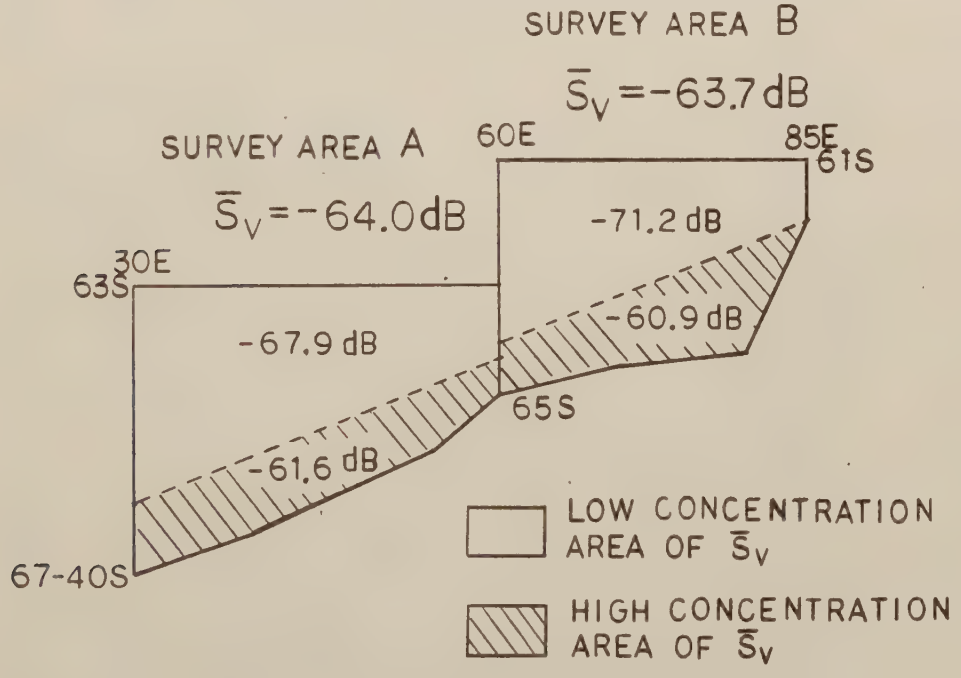


Figure 8 SV Map in the Antarctic Ocean

3.3 Comparison between Scientific Sounder Measurements and Net Sampling

Table 2 gives a comparison between aggregation densities obtained by the scientific sounder and net sampling.

To calculate aggregation density from the scientific sounder output, target strength was first determined by applying the average weight of krill caught by each net sample to equation (4).

There was not a high degree of correspondence between the two measuring methods. Several reasons can account for this such as:

(1) Accuracy and operational aspects of the echo-sounding system

(2) Efficiency of net sampling being less than 100%

(3) Time lag and spatial deviation between detection of echo and sampling by the trawl net.

For an investigation of the swarm-forming process of krill and for optimum use of the scientific sounder, it would be necessary to accumulate more data through actual trawling.

3.4 Data Comparison with Other Ships

Figure 9 shows SV data measured on board the "SHINEI MARU NO. 53" and "MANRYO MARU NO. 31" both equipped with the FQ scientific sounder.

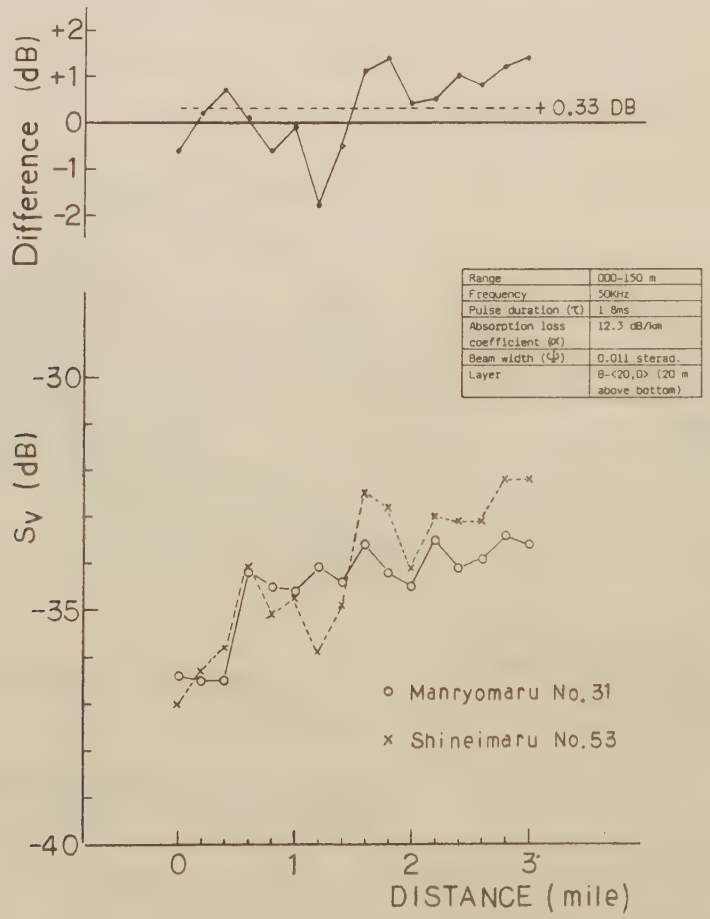


Figure 9 Comparison of SV between Two Ships

Table 2. Aggregation Densities (Scientific Sounder vs. Net Sampling)

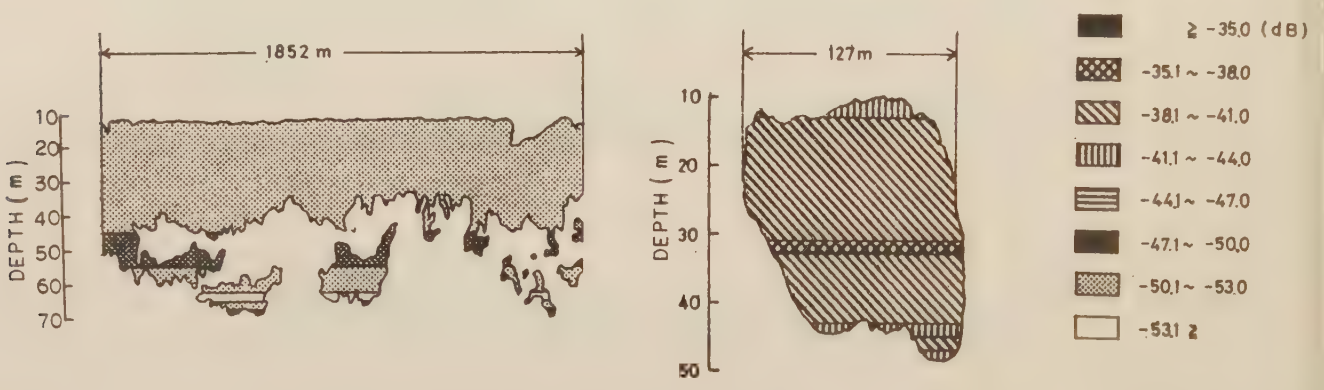
Netting No.	Station No.	Trawling Depth (m)	Integration Layer (m)	Depth of Aggregation (m)	Catch (g)	J4 (dB)	Density A (g/m)	Density B (g/m)	Remarks
02	033	21	15 - 50	11 - 53	6000	-36.3	9.9	173.00	Swarming in patches
03	035	31 - 34	10 - 60	26 - 46	3000	-36.7	3.4	171.7	"
05	056	26 - 35	10 - 50	10 -49	52700	-41.0	49.0	68.0	"
06	058	15 - 16	8 - 50	9 - 21	34800	-46.1	31.3	18.9	"
07	059	14 - 30	10 - 50	20 - 58	2200	-42.6	4.5	42.3	"
09	060-1	30 - 34	10 - 100	15 - 36	28000	-35.9	10.6	192.7	"
10	060-2	52 - 65	45 - 55	10 - 100	35600	-35.3	14.3	237.3	"
12	061	52	50 - 60	41 - 68	139600	-34.2	29.0	309.5	"
13	068-1	15	10 - 20	8 - 19	50	-36.3	0.25	183.1	"
14	068-2	13 - 14	10 - 18	7 - 23	35100	-35.5	74.8	199.7	"
15	89	36 - 40	30 - 38	19 - 51	36500	-39.1	33.9	89.5	"
17	92	24 - 27	20 - 30	8 - 36	38700	-42.3	22.6	39.7	"
18	93-1	51	60 - 70	22 - 76	19000	-37.2	15.0	127.8	"
19	93-2	28	25 - 35	20 - 59	28000	-36.9	9.5	162.3	"
20	96-1	58	55 - 70	29 - 68	12300	-40.3	8.6	82.6	"
21	96-2	45 - 50	35 - 50	30 - 84	32300	-38.1	5.2	100.6	"
22	175	36 - 45	45 - 55	16 - 53	47500	-37.8	19.14	119.7	"
23	200	58 - 90	65 - 85	20 - 100	2800	-44.8	1.69	23.3	Krill in 3 layers
24	222	60 - 68	50 - 70	37 - 87	6500	-45.1	4.0	23.0	Krill in 2 layers
25	223	20 - 22	15 - 30	15 - 29	5700	-48.1	15.28	12.8	Krill in 1 layer
26	232	26 - 30	20 - 45	30 - 93	170	-74.1	0.0075	0.033	Very weak echo in layer
28	236-1	32 - 40	25 - 45	20 - 85	14700	-46.3	1.04	20.4	Forms layers
29	236-3	47 - 55	45 - 65	10 - 78	2700	-48.9	0.76	12.1	Forms 3 layers
30	236-4	64 - 83	65 - 95	10 - 89	2700	-48.9	1.25	8.2	Forms layers
31	240-1	21 - 23	26 - 60	18 - 72	2100	-42.3	2.60	52.8	Forms 4 layers
32	240-2	45 - 53	33 - 48	20 - 75	6200	-41.8	9.16	54.4	Forms 3 layers

Density A: Measured by net sampling
Density B: Measured by scientific sounder

The measured target was pollack (Theragra chalchogramma) forming a well distributed aggregation close to the bottom of about 90 m depth. Distribution of pollack was uniform enough for spatial deviation and time lag measurement between the two ships to be negligible. With this assumption the average discrepancy in the measured SV's between the two FQ echo-sounders was 0.33 dB.

3.5 Measurement of Aggregation Density

The authors examined the difference in aggregation density between different types of krill swarms by means of VDC graphs.



(a) Layer Krill (b) Patch krill

Figure 10 Aggregation Density Comparison between (a) Layer Krill and (b) Patch Krill

In Figure 10(a) krill forms a layer distribution having a mean volume backscattering strength of approximately -50 dB. Figure 10(b) is for the krill concentration in a patch form, which shows SV values of approximately -40 dB, 10 dB higher than the former.

Other measurements also indicated that patch distribution has a higher backscattering strength than the layer distribution. On average the former showed about 10 dB (x10) higher value than the latter.

4. CONCLUSION

The FQ scientific sounder was first developed to aid the krill resources survey conducted by the "KAIYO MARU" of the Fisheries Agency of Japan, who participated in the first international biomass exploration program FIBEX of the BIOMASS PROJECT.

Target strength of krill was measured by the FURUNO FQ Scientific Sounder, and the results obtained are indicated in Figure 7, leading to the experimental equation (4). Mean volume backscattering strengths within the survey areas were charted as per Figure 8.

It would not be too bold for the authors to state that the scientific sounder achieved its initial objectives in the krill resources exploration.

The following matters can be raised as future objectives:

(1) Improvement of the system accuracy

(2) Data processing technique when several fish species exist

(3) Development of a system which enables search of wide area eliminating the error caused by sounding only the vertical direction below the ship

(4) Theoretical study and development of a system which permits movement of fish schools to be compensated by computation.

5. ACKNOWLEDGEMENT

In writing this paper the authors owe much to the Fisheries Agency of Japan for permission to use the data of the Antarctic Ocean exploration by the "KAIYO MARU". The authors would like to express sincere thanks to those concerned, especially the captain, officers and all other crew members of the "KAIYO MARU" who exerted much effort in conducting the exploration.

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SIMRAD EK400 SCIENTIFIC ECHO-SOUNDER

by

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The number of acoustic instruments installed onboard modern research vessels underlines the importance of these instruments in todays fisheries research, but it was the introduction of the echo-integrator in 1968 (Midttun and Nakken) which allowed major progress in fish stock assessment by acoustics. Simrad's latest echo-integrator is described in paper 9 of this publication. Figure 1 is a block diagram of acoustic instrumentation onboard a research vessel. The instrumentation can be divided into two parts: Systems for fish finding on the bridge and scientific acoustic equipment for quantitative fish stock measurements in the instrument room.

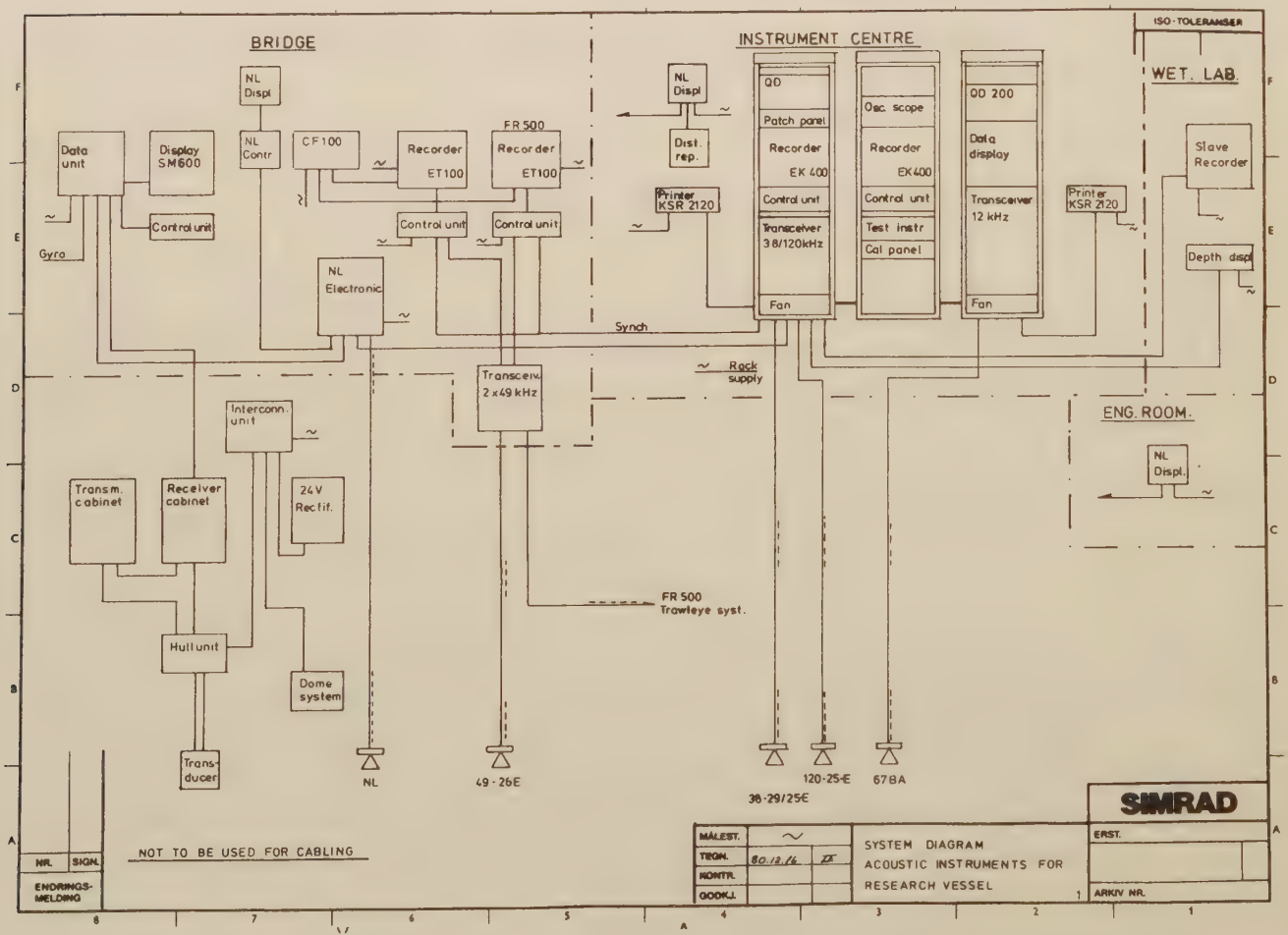

Figure 1

On the bridge is a collection of acoustic instruments similar to those found on a commercial fishing vessel; usually two echo-sounders and one sonar. One system is the main fish-finding echo-sounder, operating at 38 kHz, whilst a 49 kHz unit works as a recording unit for a Trawleye system. A Colour Display is also recommended.

The bridge also contains the SM600 Multibeam colour sonar for monitoring distribution of fish schools outside the echo-sounder beams. This is the most sophisticated and versatile sonar in the present range, with very good detection range and features like measurement of echo quantity.

Also included is a NL Doppler Speed Log because reliable speed information is necessary for the quantitative system and also for modern sonar.

Simrad equipment in the Instrument Room is often built around two EK400 Scientific Sounders, one working on both 38 kHz and 120 kHz, the most widely used combination of frequencies for fisheries research work. The other one works on 12 kHz for deep-sea surveys, and is normally fitted with a recorder which can reach 5000 m.

In addition to the hull-mounted transducers for the EK400 echo-sounders a towed body is available which contains 38 kHz and 120 kHz transducers and a depth sensor. These transducers have a dual purpose, one of which is to be used in bad weather when the hull-mounted transducers are adversely affected by aeration and noise, something which is avoided when the transducer is towed at several metre's depth. The second purpose is for work on species of fish which are close to the surface, in the zone which is blind to hull-mounted transducers. The 120 kHz transducer in the towed body is consequently mounted facing upwards.

Underwater scientific work with acoustic equipment is based on calibrated, high accuracy instruments and a complete set of test instruments is installed, because the calibration needs to be checked from time to time.

The main difference between a scientific echo-sounder and an ordinary echo-sounder is the very accurately regulated receiving amplifiers.

The gain of the amplifiers has to be varied with time (or depth), in order to obtain the same echo level at the receiver output whether the fish is at 3 m or 200 m depth, see Figure 2.

In 1980, SIMRAD finished the development of its fourth generation of Scientific Sounders, the EK400 (Figure 3).

Fig.2 Time Varied Gain

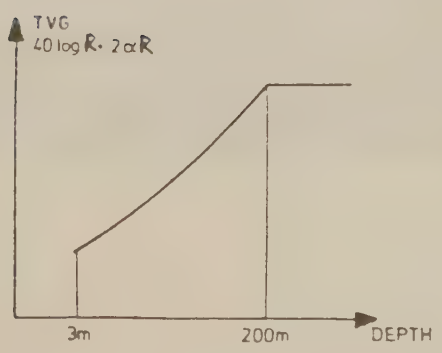

Figure 3

By applying the latest available technology, the result is a versatile echo-sounder with specifications that meet the scientists demands to do more than just detect the fish. With its very accurate, digitally controlled dual Time Varied Gain (TVG) functions, the EK400 also gives the Target Strength (TS) of a fish or the density of a fish school. It is the carefully designed preamplifiers with accompanying digital function generators with the TVG-functions stored in PROM's (Programmable Memories) that make these features possible. The preamplifiers are assembled by means of the so-called thick-film technology, giving a small and temperature-stabilized component assuring the accurate functions required. Each echo-sounder has two of these preamplifiers with two TVG-generators, making it possible to use both the 20 log R and the 40 log R laws simultaneously. Thus the 40 log R output supplies the echoes for TS analysis while signals from the 20 log R output are fed to the QD for calculation of the MVBS ($\bar{S}_v$). S_v is the reflecting property of the biomass within one unit volume (1 m^3) water.

The scientific echo-sounder is available on several operating frequencies: 12-18-27-38-49-120-200 kHz. Two of these frequencies can be combined in one echo-sounder. Which of the two frequencies to be used is chosen by means of the keyboard. Furthermore, dual frequency operation may be selected, i.e. alternate 38 kHz and 120 kHz soundings.

The EK400 also has a wider dynamic range than its predecessors. The echo from a small shrimp at 200 metres or an echo from a 60 cm cod at 10 metres will both be presented with their correct values at the calibrated output without any need for adjusting the settings of the echo-sounder controls.

All control knobs are replaced by a microprocessor based control system. The control panel has an easy to read "menu" of parameters that can be selected on a 4x4 position keyboard to give instructions from the operator to the echo-sounder and a 40 character LED-display for information from the echo-sounder to the operator. Thus an interactive mode of operation is obtained making it easy to use the scientific sounder.

Example of operation:

Choice of pulse duration: On the menu (see Fig. 4) is "23 Pulse duration". Consequently if 23 is entered on the keypad the LED display shows: "Set Pulsedur: 1=0.3, 2=1.0, 3=3.0, 4=10 ms". If the pulse duration wanted is 1.0 ms, you then enter 2 on the keypad, and the 1.0 ms pulse duration is chosen. As a confirmation of this, the display will revert to show the echo-sounder parameters selected (see Figure 4). The rest of the scientific echo-sounder selectable parameters are chosen in a similar way.

A new 0.2 m dry paper recorder has been developed for this echo-sounder. It is driven by a stepper-motor controlled by a crystal oscillator which gives an extremely accurate time base with a choice of nine basic ranges: 50, 100, 150, 200, 250, 300, 500, 600, 1000 metres.

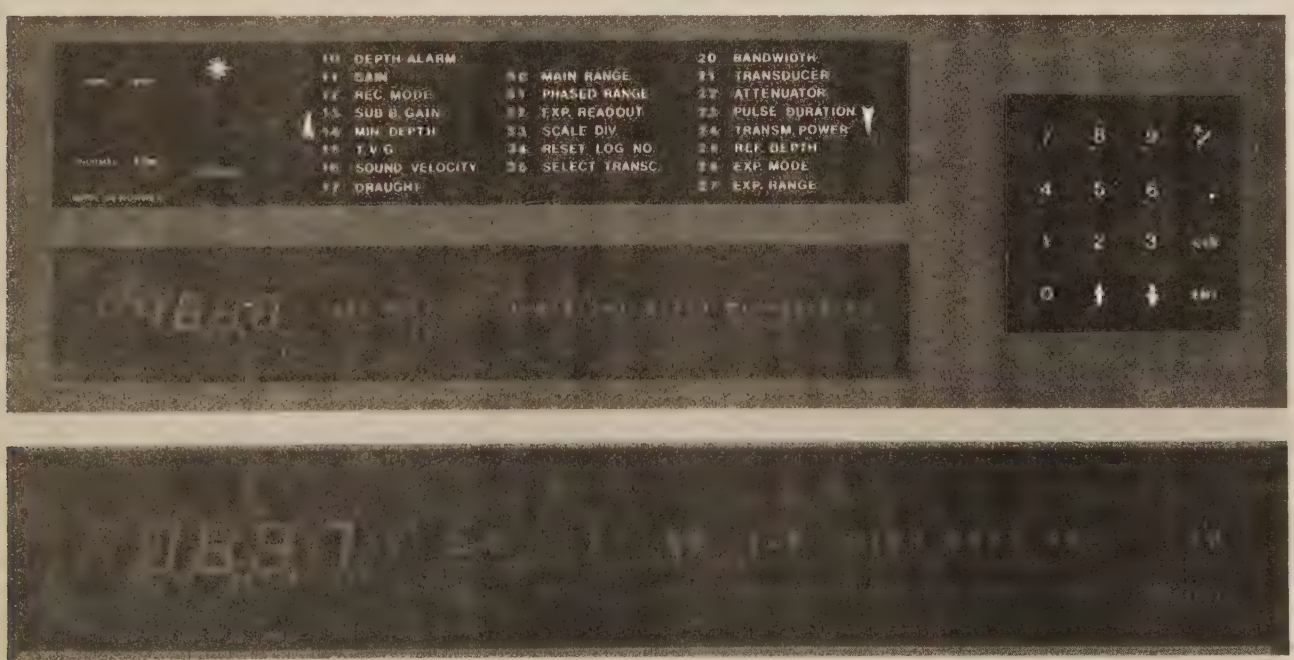

Figure 4

The most important information regarding the echogram is which depth range is in use, and with which geographic position does the registration correspond. Until now, the operator has had to write this information on the echogram, but the EK100 will do this automatically.

On the upper part of the echogram, four lines of information are presented, the two upper lines are free for the operator to print any two 5-digit numbers from the clock, navigation system etc, the third and fourth lines give the depth range registered. This information is written on the paper at any change of scale, or at regular intervals if no change occurs. At the arrival of a log marker (every 0.1 or 1 nautical mile) a 3-digit number is written. This number will be incremented automatically by one at every log marker. It can be preset to any starting value from 000 to 999 from the keyboard.

All Simrad scientific echo-sounders have a built-in transmitter of 2500 watts maximum as a standard. Output power is optimized for the transducer connected; for the largest transducers an additional 2500 watts transmitter may be plugged into the transceiver giving 5000 watts altogether. The two lowest frequencies, 12 and 18 kHz, may be boosted up from 4000 to 8000 watts with an additional transmitter.

The depth below the transducer is displayed on a 5 digit LED-display positioned on the Control Unit, the reliability of this depth readout depends to a large extent on the performance of the bottom detector. For the EK400 a new bottom detector has been developed which automatically adjusts the detection threshold to the varying bottom conditions. Furthermore, the bottom pulse is only allowed within a "window", i.e. the depth interval within which the next bottom pulse is expected to arrive. To avoid a false bottom pulse on dense fish schools, a minimum acceptable depth can be programmed via the keyboard.

All the functions available by means of the well known SIMRAD MC Scale Expander are now built into the scientific echo-sounder, they are accessible via the keyboard and the LED-display. An expanded scale can be selected from any depth up to 999 metres in the midwater mode, or it can be locked to the bottom. Expanded depth scales are selectable from 2.5 - 5 - 10 - 25 - 50 - 100 or 250 metres. The possibility of displaying these expanded ranges across the full width of the recording paper gives an additional choice of ranges with phasing steps of one metre.

For recording and replaying echo signals a tape recorder synchronizer and interface unit are included in the EK400 scientific echo-sounder and for checking the performance of the EK400, a built-in Test Generator is provided.

This scientific echo-sounder system offers flexibility in the assembly of an acoustic research instrumentation system. Figure 5 indicates the many possibilities.

SIMRAD EK400 Scientific Sounder System

BASIC SYSTEM

SUPPLEMENTARY EQUIPMENT

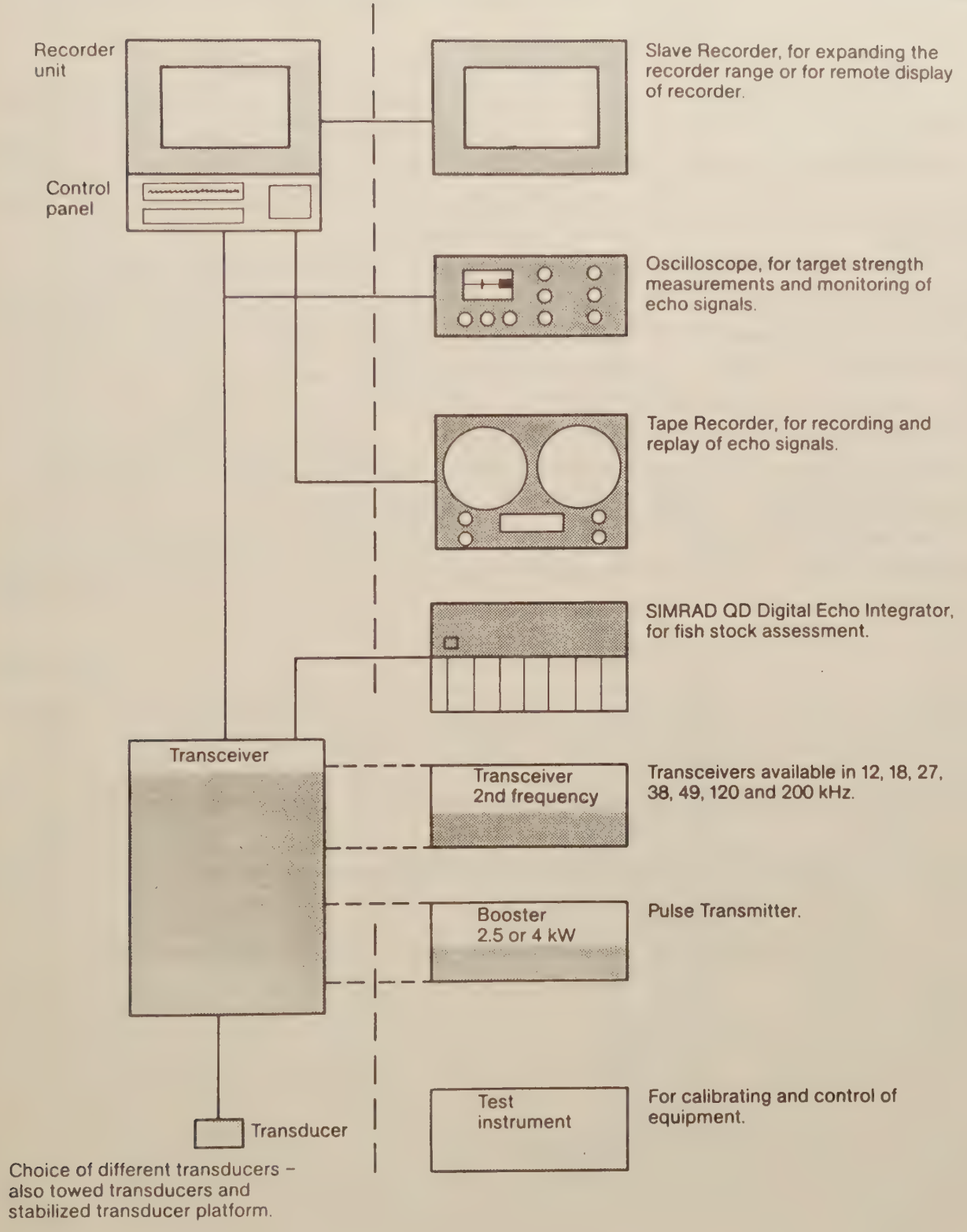

Figure 5

For complete specifications of the SIMRAD EK400 Scientific Sounder System, please see Appendix 1.

To carry out quantitative measurements, the echo-sounder should be calibrated by through water measurements, and the vessels are equipped with sufficient test instruments for this calibration. By means of these calibrated echo-sounders, it is possible to measure the TS of a fish, and when the correlation between the TS and the fish size is known, the fish size is obtained.

Towed transducers for quantitative measurements in rough weather:

In rough weather the performance of a hull mounted transducer is rather limited due to the aeration beneath the vessel. To avoid this limitation, a towed body was developed in order to get the transducer below this aerated layer. This towed body was first installed on the R/V "G O Sars", and the results were so convincing that the "Dr Fridtjof Nansen" and the "Michael Sars" are now similarly equipped.

The towed body contains a 7°x7° downward-looking 39 kHz nickel transducer and a 10° upward-looking 120 kHz ceramic transducer. The main problem in designing the towed body was to obtain safe operation in rough weather and with the vessel cruising at a speed of up to 12 knots. To achieve this, a special handling crane was designed and the towed body is put into the water before it is released from the crane. See Fig. 6 . Likewise, the body is recaptured by putting the crane arms into the water. Beside going below level of aeration in the water, the towed body also gives a stable platform for the transducer, unaffected by the ship's roll and pitch movements.

Another advantage of the towed body is the possibility of better detection of fish close to the surface. The upward-looking 120 kHz transducer may be tilted sideways by up to 30° from the vertical, to avoid the ships wake.

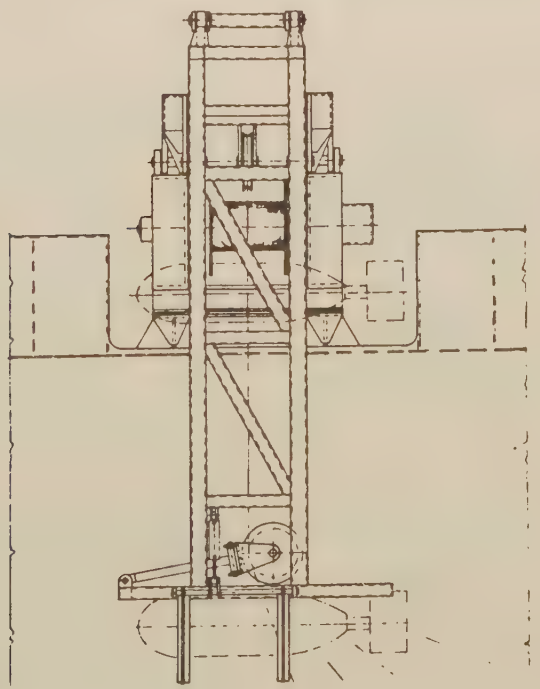

Figure 6 - Towed body with handling crane, view from ships side

Stock assessment in freshwater:

Freshwater fisheries now contribute approx 10% of the total world catch, and there is an increasing interest in research work in this field in order to properly utilize the resources.

No special instrument has been available for scientists trying to make fish stock assessments in freshwater; standard fish-finding echo-sounders have been used.

The boats used in freshwater are often very small, and only light weight, portable equipment is suitable. In order to meet the users requirements, SIMRAD has developed a new echo-sounder system intended for fish abundance estimation.

The EY-M Portable scientific echo-sounder has very accurate TVG-functions, and its echo signals can be recorded on a standard cassette tape recorder. These can be replayed ashore and the echo signals processed, e.g. by means of the SIMRAD Digital Echo-Integrator System (QD) or the QM analog integrator, Larsen (1983).

Although mainly intended for acoustic stock assessment in freshwater, the equipment is also well suited for installation in smaller boats doing scientific work at sea.

The intention of this paper is to present briefly the range of acoustic equipment with additional instruments available for fish stock assessment. The combination and interconnection of the different instruments depend on the field of operation of the research vessel. Assistance should be called for from the instrument producer in the planning of new projects so that the right instrument configuration is chosen for the purpose.

REFERENCES

Forbes, S.T. and O. Nakken (eds), Manual of methods for fisheries resource survey and appraisal. 1972 Part 2. The use of acoustic instruments for fish detection and abundance estimation. FAO Man.Fish.Sci., (5):138 p. Issued also in French and Spanish

Larsen, B.H., An interface for the EY-M echo-sounder and the QM echo-integrator. FAO Fish Circ., 1983 (754):30 p.

Midttun, L. and O. Nakken, Counting of fish with an echo integrators. ICES CM. 1968/B:17:7 p. 1968 (mimeo)

APPENDIX 1

EK400 ECHO-SOUNDER

Technical specification

Mains supply: 110/220 V AC ± 5%

Environmental specification

As given in Simrad's general standard (available on request). (Temp. range from -10 to +55° Centigrade).

Transceiver section:

The cabinet has room for two complete transceivers, with a possibility of doubling the transmitter to increase output by 100%. Transceiver frequency choice: 12,18,27,38,49,120 and 200 kHz. In a standard dual frequency cabinet, any combination of frequency is possible, except use of 12 and/or 18 kHz which require extended cabinet versions.

Transducer connections:

Transceivers are adjusted to 60 Ω transducers. Both ceramic and nickel transducers can be used. Each transceiver has connectors for four single-beam or two double beam transducers, selectable via keyboard on control panel. Internal precision oscillators can be selected as "transducer" no. 5 and 6 for testing purposes. Transmitter output can be preset to match maximum output power as specified for each of the transducers, automatically preventing cavitation at the transducer face.

Receiver gain:

The overall voltage gain from the 60 Ω input to the calibrated output is 85 dB (max).

Overall gain can be reduced by using attenuators of 0, -10 dB, -20 dB or -30 dB, selectable via keyboard.

Calibrated outputs

Two calibrated outputs are available on each transceiver: one with 20 logR TVG and one with 40 logR TVG function.

Bottom detector/digitizer

The bottom detector works on the 20 logR signal (correct for bottom echo) and has automatic detection level adjustment, min. detectable depth setting via keyboard and tracks bottom with an automatic -10 +20% depth "window". Digitial output to dataplug and display is from 0.0 to 9999 metres (dropping the 0.1 digit when depth exceeds 999.9 metres). Depth alarm is audio, - choice of "deeper than" or "shallower than" - 0000 to 9999 metres via keyboard.

Pulse durations/bandwidths

Frequency	Pulse duration in ms	Bandwidth in Hz (recommended values in frames)		
12kHz	1	1000	330	100
	3	1000	330	100
	10	1000	330	100
	30	1000	330	100
18kHz	1	1000	330	150
	3	1000	330	150
	10	1000	330	150
	30	1000	330	150
27,38,49kHz	0.3	3300	1000	330
	1	3300	1000	330
	3	3300	1000	330
	10	3300	1000	330
120kHz	0.1	10000	3300	1000
	0.3	10000	3300	1000
	1	10000	3300	1000
	3	10000	3300	1000
200kHz	0.1	10000	3300	1500
	0.3	10000	3300	1500
	1	10000	3300	1500
	3	10000	3300	1500

Signal levels: noise level[1]) to +15dB//1 V rms.
Output impedance: 50 Ω
Frequency: Same as transceiver frequency.

TVG
TVG functions are digitally controlled according to sound velocity setting, resulting in a guaranteed accuracy of ±0.5 dB at any point.

[1]) Selfnoise 38 kHz, 330 Hz
Bandwidth: -56 dB//1 V rms.

TVG ranges:

Frequencies	(dB/m)	duration 40 logR (m)	duration 20 logR (m)
12 kHz	0,0010	290	1263
18 kHz	0,0021	280	1029
27 kHz	0,0044	264	773
38 kHz	0,0080	242	581
49 kHz	0,0122	222	464
120 kHz	0,0366	108	110
200 kHz	0,0546	94	90

Recorder:
Ranges

EK-400 comes in two basic range types

a) Basic Ranges from 50 to 1000 metres

b) Basic Ranges from 250 to 5000 metres

There are 9 basic ranges: Each range can be phased in steps of one main scale division

	1	2	3	4	5	6	6	8	9
a)	50	100	150	200	250	300	500	600	1000
b)	250	500	750	1000	1250	1500	2500	3000	5000
No of main scale divisions on paper	5	5	3	4	5	3	5	6	5
Total no of phase steps	12	12	7	10	12	7	12	15	12

Sound velocity

Sound velocity is variable from 1400 m/s (fresh water at freezing point) to 1547 m/s (temp: 25°C, 35°/°° salinity) in 22 steps.

Draft can be set in 0.1 m - steps from 0.0 to 9.9 metres.

Bottom echo presentation (Rec. mode)

Normal, dynaline, contour line.

Data printout

From data input plug
Upper scale display reading
Lower scale display reading

At every change of scale, or at regular intervals if no scale change occurs, or at input command, the digits as given above will be printed out on top of the paper.

Input data are 5x4 BCD parallel with two strobe inputs, strobe upper line, stobe lower line.

When log marker occurs, printout will be giving log marker no. from 000 to 999. with automatic interval increment. Starting log no. can be preset from the keyboard. Log marker and <<man marker>> on keyboard produces a vertical line across the paper.

Integrator printout

EK-400 connects directly to the Simrad QD echo integrator and presents the limit of its integration layers as dotted lines on the paper. It also presents the integral value of two integrator channels as rising lines (one single and one double) across the paper to enhance integrator value "judging" on surveys. Presentations can be turned on and off on QD operator's panel.

Paper

Type:	Dry TP 8
Width:	8" (203 mm)
Scale width:	185 mm
Length of roll:	25 metres

Paper speed

1. Paper speed is variable from 2-60 mm/min by manual control at fastest stylus speed. Paper speed range is automatically reduced according to basic range.

2. Paper speed can be controlled from ships log (2-60 mm/min corresponding to 0-10 V input). In this case paper speed is independent of basic range. Accuracy (linearity): better than ±10%.

Scale lines

Scale lines are printed on the paper by the recording stylus, thus avoiding all problems of zero alignment of the pen and paper positioning. Scale lines are printed as light grey lines through both white and blackened paper.

Depth readout

Depth in metres or fathoms is given by five digits 999.9 max on both display and data output.

Data output is straight BCD parallel steady state, (5x4 connections with "lost bottom" and "data changing" pulse.

Standard TTL levels. Choice of either pos. or neg. logic.

Synchronization

For the use of several depth sounders simultaneously, - or for the use of slave recorders, the recording unit can be synchronized to a "master" EK-400. Relative phasing of all units are done by push-button on recorder units. This facility minimize interference problems when operating at several frequencies simultaneously.

Tape recorder

EK-400 connects directly to any high quality stereo tape recorder via standard phono plugs. Signal frequency is 12 kHz and sync. frequency is 3584 Hz.

Recording amplifier

Recorder gain is adjusted separately for transmitter-pulse-to-bottom and for sub bottom echoes in nine 3 dB steps (from 0 to 9). Recorder has maximum blackening and minimum signal (threshold) control. Threshold can also be controlled via ext. input (integrator).

Cabinet version

Dimensions

Recorder Unit AR800:	400x483x290 mm
Control Unit MV:	177x483x290 mm

Transceiver TR101

38-200 kHz:	570x510x320 mm
12- 18 kHz:	933x510x320 mm

Rack version

For mounting in standard 19" rack.

Recorder:	9 rack modules
Control Unit:	4 rack modules
Transceiver:	38-200 kHz 12 rack modules 12-18 kHz 21 rack modules.

AN ECHO-SOUNDER SIGNAL SIMULATOR FOR ACOUSTIC SURVEY DESIGN AND TRAINING [1/]

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SUMMARY

As a part of a new modular simulator concept for training in the use of navigation and fish-finding equipment Simrad have developed a echo-sounder simulator. This signal simulator can be used in conjunction with almost any type of echo-sounder in the frequency range of 10 to 200 kHz. When used with a scientific echo-sounder like the EK400, the QD echo-integrator and other additional equipment can be connected and used as in real life.

The simulator is connected to the echo-sounder in the place of the transducer and it senses the transmitter pulse power, the signal frequency and the pulse duration, then it generates echo signals according to the chosen transducer parameters and the models of scattering layers, schools of fish, aggregations of single fish, wrecks and bottom topography chosen by the instructor. The simulator has a simple 'own ships' model which allows the instructor to sail the vessel through the exercise area.

Total volume of the scattering layers, the schools of fish and single fish aggregation are defined by multi-cylinders and can easily be calculated. The mean value and the variation of the volume backscattering strength and the target strength are set by the instructor and can be varied during any exercise. Total biomass in the area is thus known and the result of the abundance estimate can be checked.

Each individual module in the new simulator concept is a complete signal simulator providing antenna signals to the most common used navigational instruments as Loran C, Decca Navigator, Radio Direction Finder, Omega, Radar and Navigational Depth Sounder. A sonar trainer is also part of the system. Through a vessel simulator with ships steering controls and a databus system, a complete set of bridge instrumentation can be built up and made to work as on the bridge of a real research vessel.

1. INTRODUCTION

Mapping and quantifying fish resources is a vital task both for the individual fishery nation and for the international bodies involved, so acoustic equipment such as sonar and echo-sounders are vital tools for the mapping and monitoring processes. Both the methods and the equipment used for fish stock assessment have undergone rapid development. The results obtained and the accuracy of the estimates claimed are dependent on several parameters, but apart from the methods and the equipment used, the training and routine of the team that are responsible for the survey and carry it through are of great importance. Among the team-members we will find biologists, oceanographers, instrument operators, electronic engineers, fishing gear specialists et al. Obviously it is important that all team members performing the measurements and having an influence on

1/ Paper presented at the ICES/FAO Symposium on Fisheries Acoustics, June 1982, Bergen, Norway (Contribution no. 56)

the estimate given, should have good knowledge of the methods used and the equipment involved. No doubt great effort has been put into this training, but the facilities for the team drilling are limited and the training often take place on board the research vessel during the actual surveys. This paper presents a newly developed echo-sounder signal simulator which is well suited for planning of a survey and training of the scientific team responsible for the stock assessment.

1.1 Design criteria

The list of design criteria used as a guide for the development is given below. All criteria were fulfilled, a good indication of the simulators realism and flexibility.

a) Echo-sounders normally used in fisheries research and fishing should be used with the simulator without modification.

b) The simulator should produce electrical signals corresponding to the signals received through the echo-sounder transducer. The transducer specifications to be altered and set by the instructor.

c) The simulation should take into consideration media parameters such as frequency dependent absorption and ambient noise.

d) The simulator should contain a simple own ship's model where speed, course, roll, pitch and heave of the vessel can be altered and set by the instructor. Speed dependent ship's self noise to be included.

e) A reasonable bottom area to be simulated, based on definition of a number of bottom points with corresponding position, depth and bottom condition. It should be easy to load new bottom maps into the simulator.

f) The mathematical model for scattering layers, schools of fish and single fish aggregation should facilitate close simulation of real signals with the use of well defined parameters.

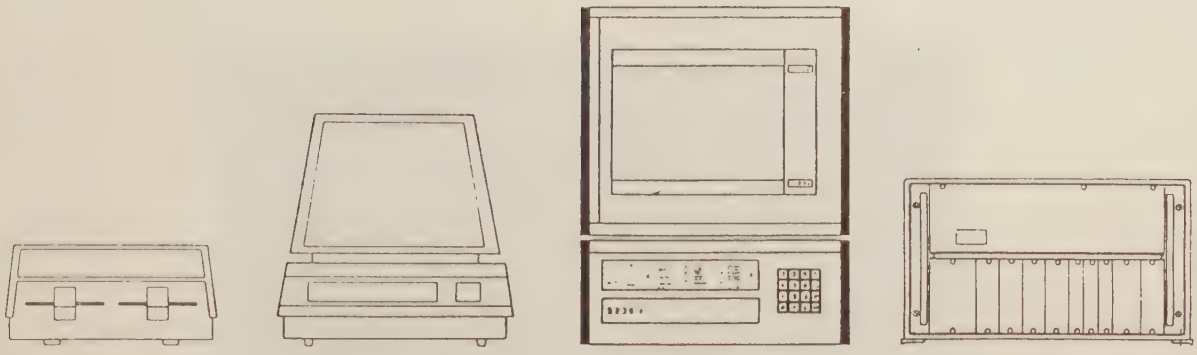
g) Operation of the simulator should be easy and require no special programming skill.

h) The echo-sounder simulator should form part of a modular simulator system.

2. GENERAL DESCRIPTION

This simulator can be used in connection with almost any type of echo-sounder and the instructor has almost unlimited possibilities in setting up exercises. It is thus well suited for training and education in all fields where an echo-sounder is being used. The description below will be restricted to the use of the simulator for stock assessment survey using the SIMRAD EK400 Scientific Sounder and SIMRAD QD Digital Echo-Integrator.

Figure 1 shows the units.



Dual Drive
Floppy Disk

SIMRAD XE202
Fish Finding Echo-
Sounder Simulator

SIMRAD EK400
Scientific Sounder

SIMRAD QD
Digital Echo-Integrator

Figure 1 Set up for stock assessment survey training

The EK400 and the QD are interconnected as normal. The only connection necessary between the XE202 and the EK400 is a cable from the simulator to the transducer terminals in the echo-sounder.

An 'own ship' facility in the simulator allows sailing in the simulated area with varying speed and course. The instructor can also set roll, pitch and heave movements of the simulated vessel. A signal for each nautical mile sailed is generated in the simulator and this is fed to the log input of the EK400 giving the mile mark for the recording and the computation in the echo-integrator. The simulator detects the signal frequency, power and duration of the transmitted pulse of the connected echo-sounder, and it generates echo signals on the same frequency. Echo-sounders in the frequency range from 10 to 200 kHz can be used. All controls on the echo-sounder except the transducer selector can still be used in the normal way but changes of the transducer parameters must be set via the keyboard on the simulator. A great effort has been made to make the communication with the simulator as convenient and simple as possible without losing flexibility.

The communication is based on the use of the display and keyboard.

Figure 2 shows the menu of the pages to be called on for communication with the simulator.

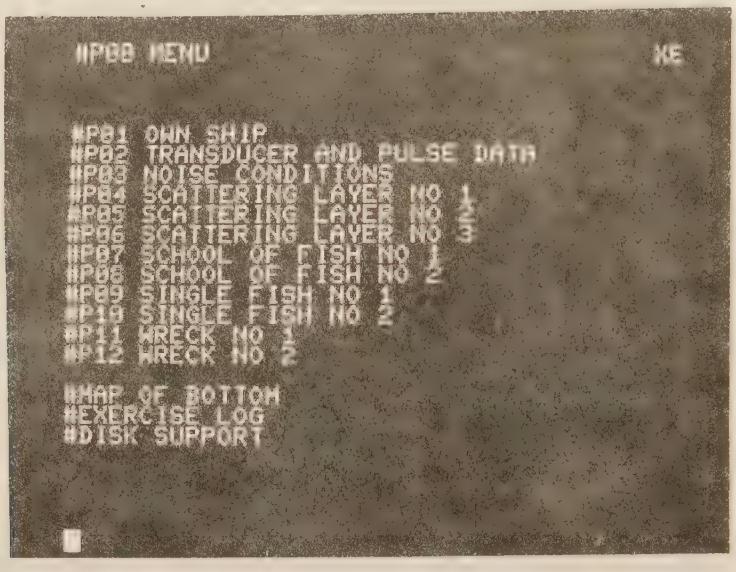


Figure 2 Page #PØØ containing the simulator menu

As an example of the communication page #PØ1 OWN SHIP will be explained. See figure 3.

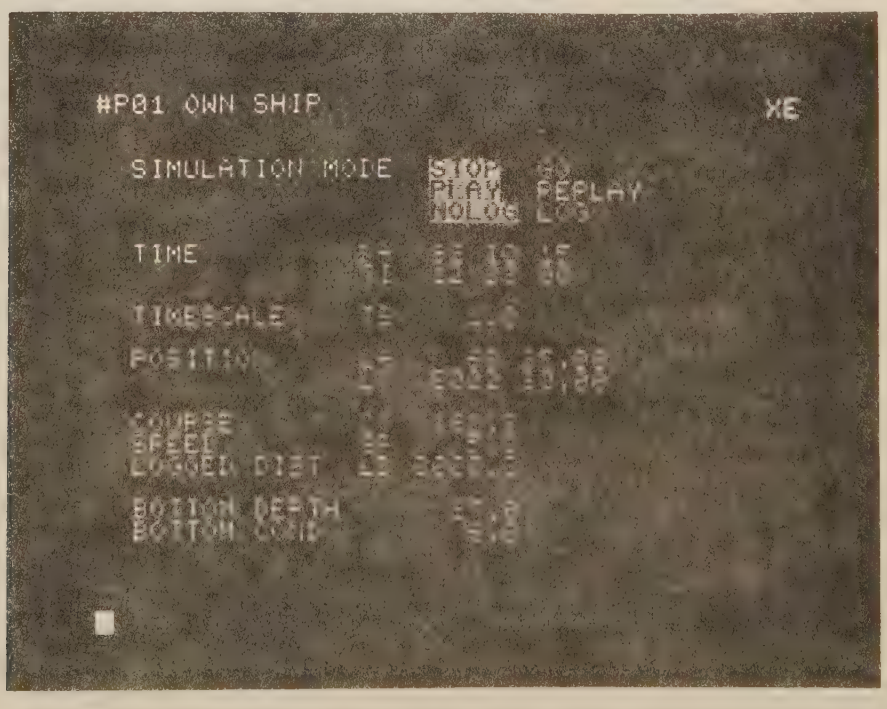


Figure 3 Page #PØ1 containing 'Own ship' information

The format of the page is designed to give the best possible overview. Information on the page is divided in three categories:

1. The name of the variable/parameter,
2. the mnemonic to be used and
3. the value of the variable/parameter currently used for the simulation.

If the position of the simulated 'own ship' should be changed, the new position is entered by typing the mnemonic and the new value, then entering the latter by pressing the Return key.

Ex. LA N 62 27.ØØ RETURN

The denomination of the numbers is not given on the display and if in doubt the handbook must be consulted.

3. FUNCTIONS AND EFFECTS TO BE SIMULATED

The basic design philosophy asked for a model of the seawater medium insonified by the simulated transducer beam and giving echoes back from the different targets hit by the acoustic waves. The mathematical model in use includes the following parameters:

a) Transducer beam pattern (simplified)
b) Geometrical spreading of acoustic waves
c) Frequency dependent absorption coefficient
d) Target Strength of single targets
e) Volume back-scattering strength
f) Bottom depth and back-scattering strength
g) Ambient noise and ship's self-noise
h) Ship's position, course and speed
i) Ship's roll, pitch and heave

3.1 Volume definition of scattering layers, schools of fish and single fish aggregations

The volume for all three categories is defined in the same way.

Four cylinders (cylinder A, B, C and D) which can be dimensioned and positioned by the operator are used to describe the volume.

A picture of one of the pages for scattering layers is shown in Figure 4.

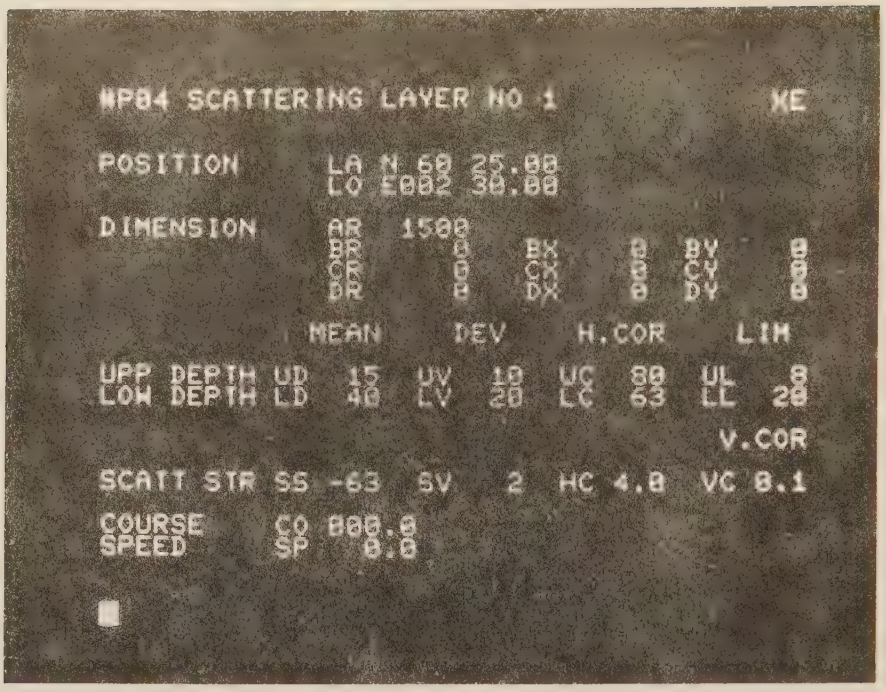


Figure 4 Page #P04, Scattering layer information

From figs 5 and 6 the different parameters used for the definition of the back-scattering volume can be derived.

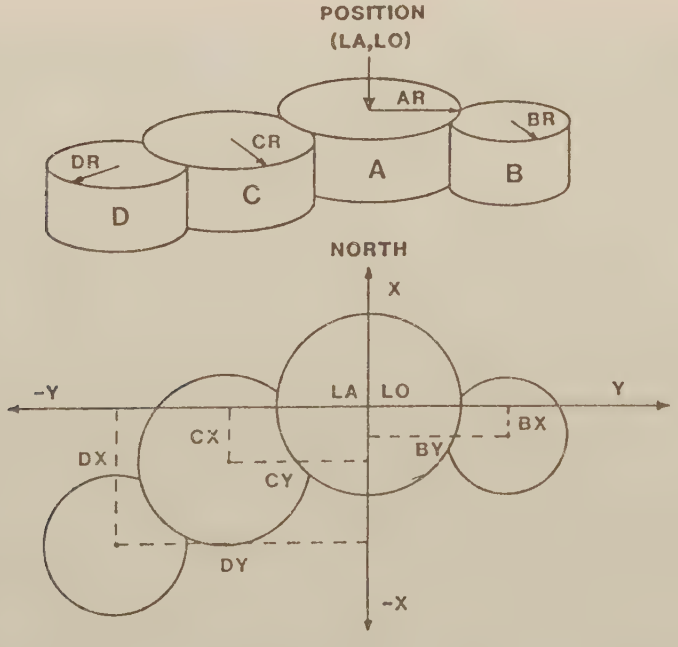


Figure 5 Volume parameters and mnemonics

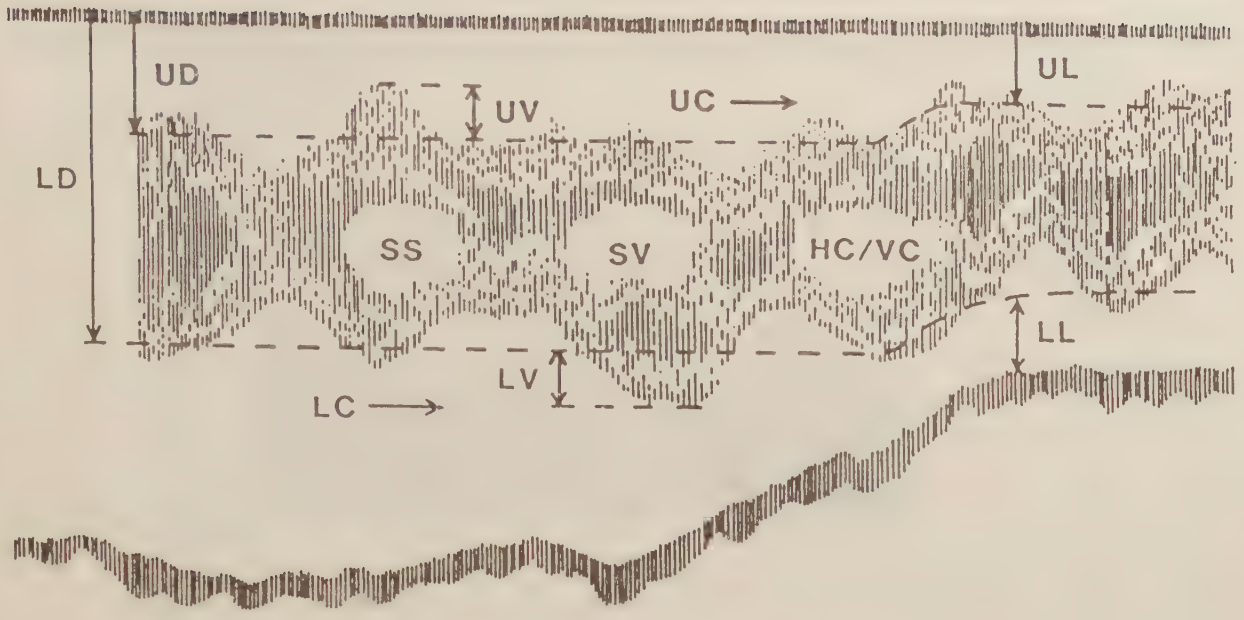


Figure 6 Boundary layers and back scattering strength parameters and mnemonics

By the parameters upper depth (UD), upper variation (UV) and upper correlation (UC), all given in metres, the upper boundary layer of the back scattering volume can be modelled. The flexibility obtained by the chosen volume description allows the operator to copy a wide variety of scattering layer configurations.

3.2 Volume back-scattering strength simulation

Within the defined volume the volume back-scattering strength can be set thus allowing different patterns to appear on the echogram. In figs 4 and 6 the parameters used for defining the volume back-scattering strength can be derived.

SS gives the mean volume back-scattering strength in dB and SV the variation in dB. SS-55, SV4 wll give a volume back-scattering strength varying between -59 dB to -51 dB. In order to describe the patchiness of the scattering layer both a horizontal (HC) and a vertical correlation factor (VC), the dimension given in metres, can be defined. In fig. 7 the values of density variation (SV) in dB and density correlation in horizontal (HC) and vertical (VC) direction in metres are changed, keeping the mean volume back-scattering strength (SS) in dB the same. In the copying process the echo-sounder recordings have lost some of the grey tones and the copies appear with greater contrast than the original.

Figure 7 Scattering layer pattern versus change in density and correlation parameters

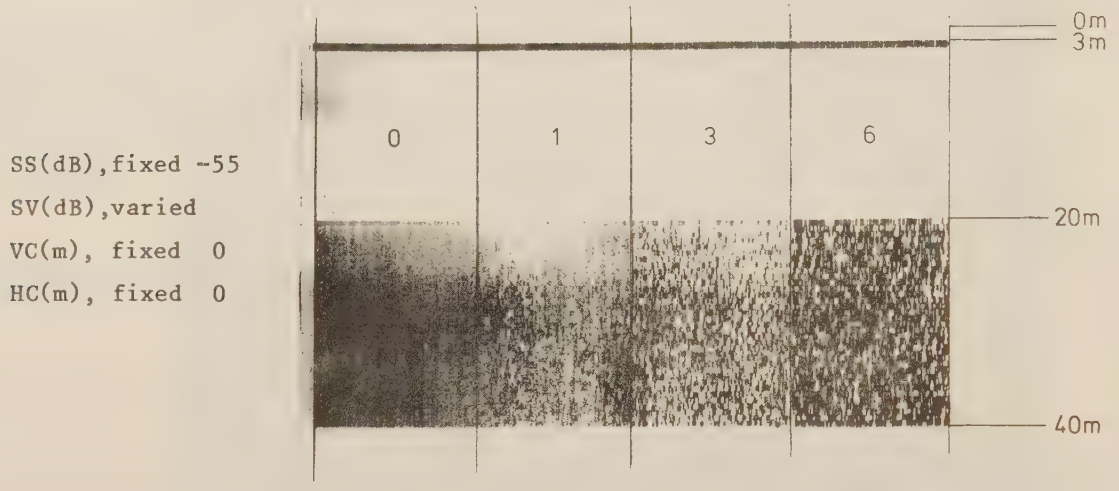


Figure 7(a) Variation in volume back scattering strength (SV)

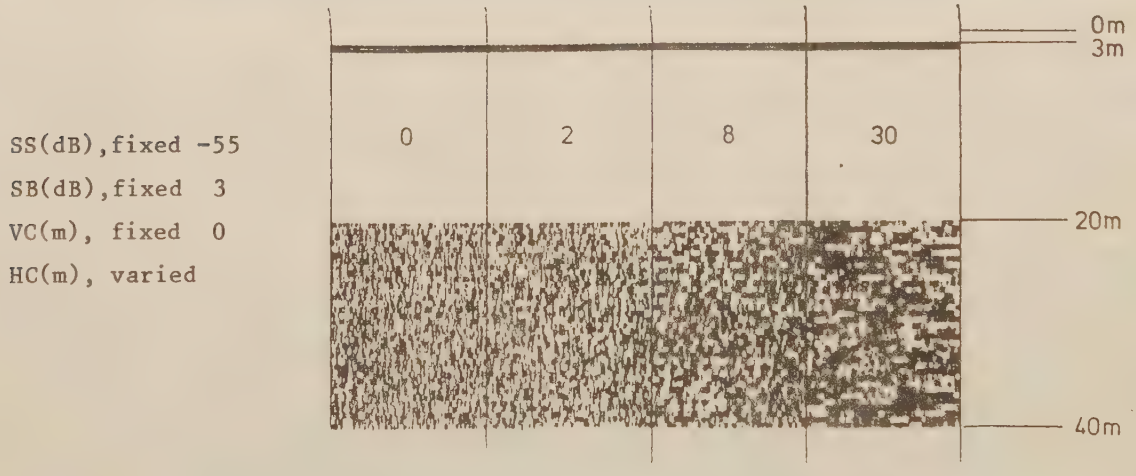


Figure 7(b) Variation in horizontal correlation (HC)

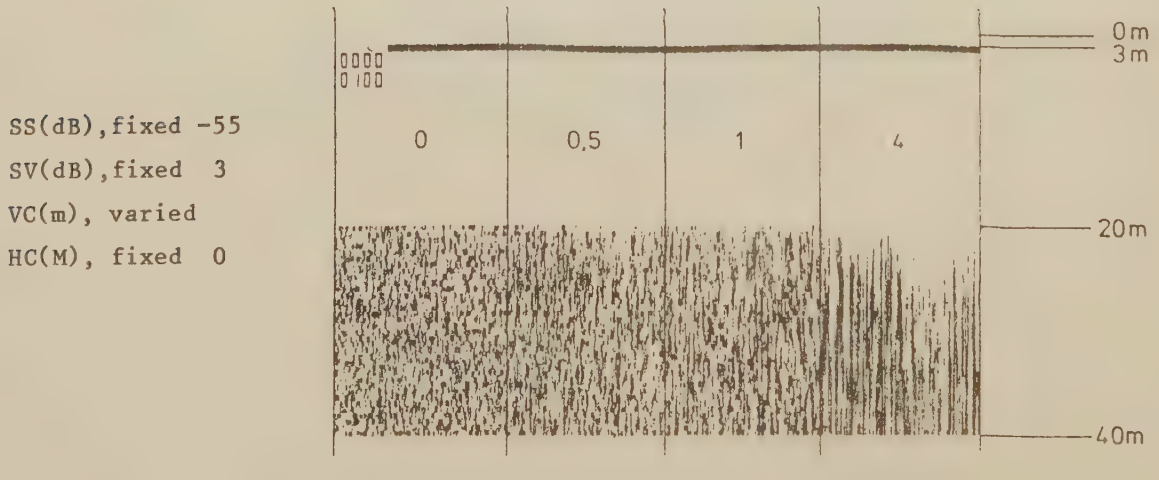


Figure 7(c) Variation in vertical correlation (VC)

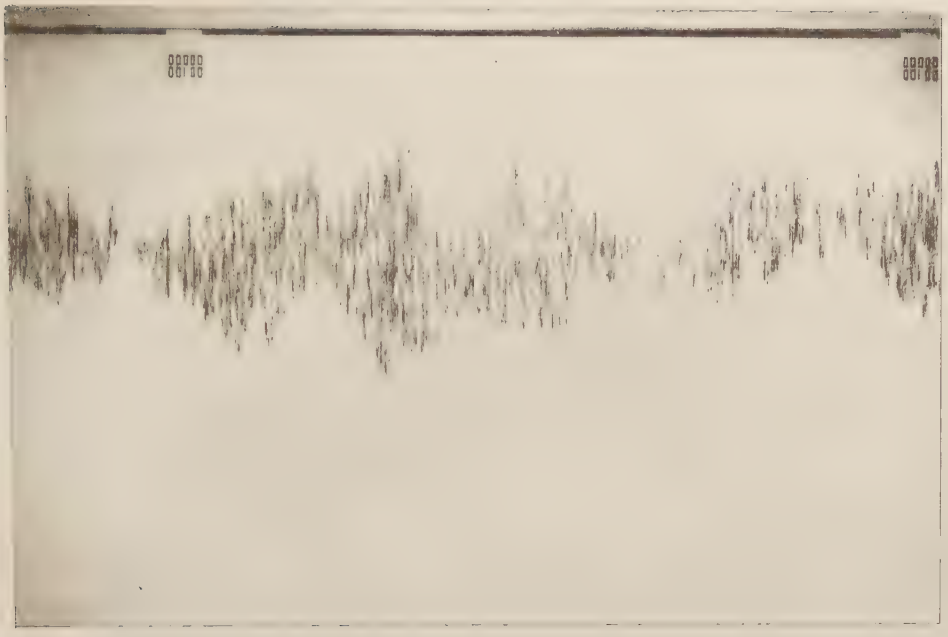


Figure 8 Scattering layer

The recording in fig. 8 is obtained with the following settings. Refer to fig. 6 for the mnemonic used

UD3Ø, UV4Ø, UC1ØØ, UL1Ø

LD3Ø, LV6Ø, LC2ØØ, LL1Ø

SS-55, SV3, VC1.Ø, HC4.Ø

The transducer beam width (BA) is 10 degrees and the vessel speed (SP) is 5 knots.

The difference between a scattering layer and a school of fish can be a matter of definition and is mainly given by the volume and the density, pages for the two categories therefore have the same format. There is full freedom in putting one scattering layer inside the other. The echo from the two layers will add to each other according to the densities. When the simulator is used to closely copy recordings taken in real life this is of great help.

Figure 9 gives an example of a possible design of mixed scattering layer and in fig. 10 there are samples from the recordings obtained on a 120 kHz EK400 Scientific Echo-Sounder. The values used for the parameters determining the density of the scattering layers and the upper and lower boundary layers of the scattering volume are given in the table.

Scattering layer #	SS	SV	HC	VC	UD	UV	VC	LD	LV	LC
#PØ4	-52	2	1Ø.Ø	Ø.5	15	1Ø	5Ø	4Ø	2Ø	1ØØ
#PØ5	-49	2	6.Ø	1.Ø	2Ø	1Ø	2Ø	3Ø	1Ø	3Ø
#PØ6	-43	1	4.Ø	2.Ø	25	3	2Ø	3Ø	3	2Ø

The transducer beam width (BA) is 20 degrees and the vessel speed (SP) is 5 knots.

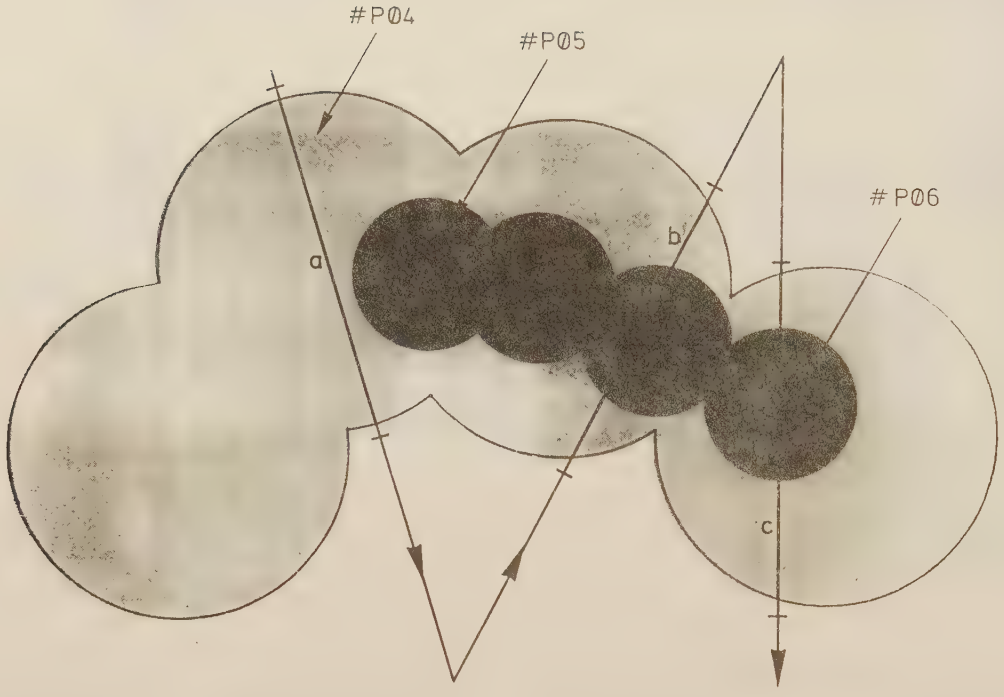


Figure 9 Mixed scattering layer design

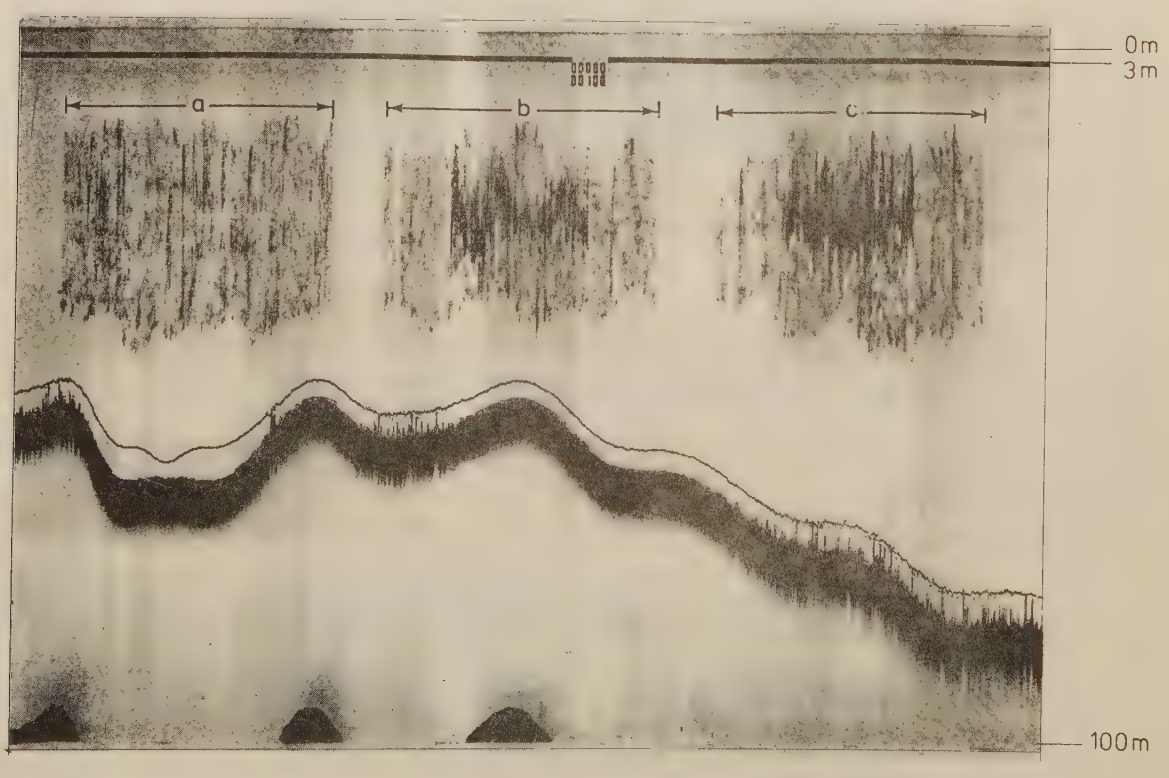


Figure 10 Recordings taken along the indicated course line in figure 9

Knowing the total mean volume of the scattering layer and the mean volume back-scattering strength allows one to calculate the total biomass in the area provided that the relationship between biomass and volume back-scattering strength is known. As shown above different scattering layers can be simulated and a realistic stock assessment survey can be set up.

3.3 Single fish simulation

The volume for the single fish aggregation is defined as described under 3.1. Within this volume the density of fish and the target strength of the fish can be defined by the operator. Figure 11 illustrates the definition of loosely aggregated single fish.

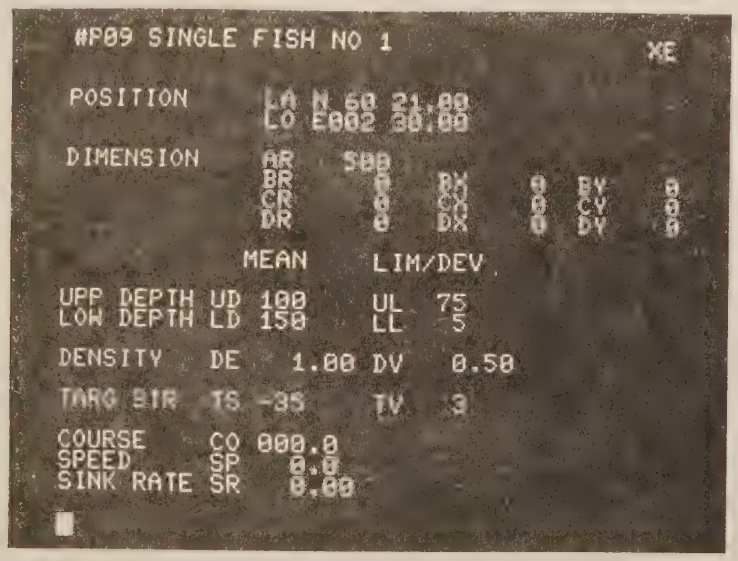


Figure 11 Single fish aggregation

The density DE is given as number of fish within 1000 m^3 of water. This number can also vary within a given limit defined by DV, density variation. DE 2.ØØ, DV 1.ØØ will give density variation between 1 and 3 single fish in 1000 m^3 of water. Target Stregth, TS, is given in dB, so also is the target strength variation, TV. By entering TS = -35, TV 3 the simulated single fish will vary between -38 dB and -32 dB. The variation is stochastic but as soon the fish enter the transducer beam the target strength will remain constant through the beam.

Figure 12 shows recording of single fish of TS -32 dB at approx. 90 m depth recorded at 5 knots and 10 knots speed. The transducer beam width is 20 degrees.

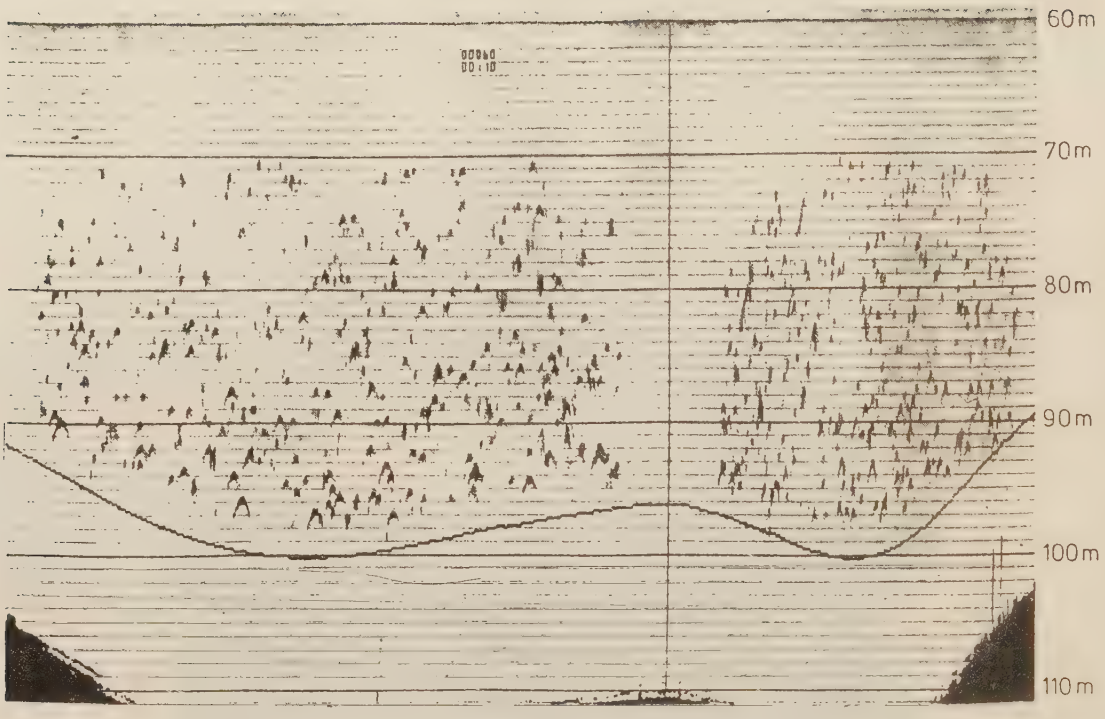


Figure 12 Single fish recording

The recording is obtained on an EK400 scientific echo-sounder working at 120 kHz with a pulse duration of 1 ms and a pulse power of 1400 watts; settings used on the simulator are given in fig. 11. The transducer beam angle is 20 degrees and the vessel speed is 5 knots during the first crossing of the single fish aggregation and then 10 knots after the vessel has turned.

3.4 Sea bed simulation

The approach to the seabed simulation allows the operator to define the seabed area (called a bottom map) as desired. One bottom map can be made up from 200 bottom points. Each point is defined by its position, depth and bottom condition indirectly, stating the reflection coefficient. If the seabed topography is broken and a detailed description is desired the 200 points at disposal for the bottom map construction will cover a relatively small area, but if details are of little interest the 200 points will cover large areas. When the simulated 'own ship' is at a position corresponding to one of the defined points, the depth given will be measured. For position in between, an interpolation is used.

4. CALCULATION OF SINGLE FISH SIMULATION

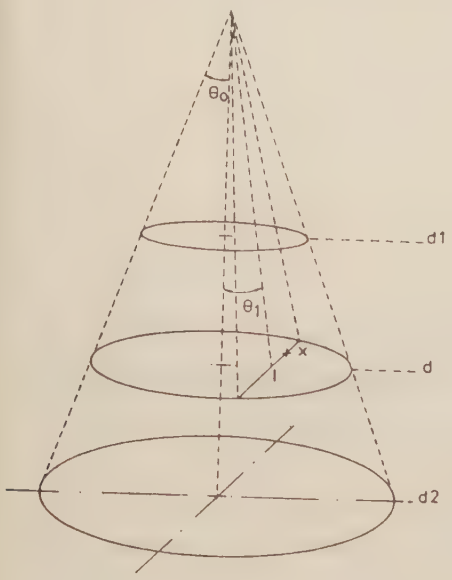


Figure 13

To give an example of the models employed, we describe the simulation of single fish echoes. Assume an aggregation of fish between depths d_1 and d_2 within a density of n individuals per unit volume.

A vertical acoustic beam with circular cross-section and a beam width $2\theta_0$, sweeps through the aggregation at a relative speed v. See fig. 13.

Thus, we find

$$\tan \theta_0 (d_2^2 - d_1^2).v.n$$

fish are entering the beam for each unit of time. On average the same number will of course be leaving, but the model must provide more than just averages. Outside the beam averages are appropriate, inside we see the fish as individuals.

We therefore compute the integral

$$\int_{-\infty}^{t} \tan \theta_o \, (d_2^2 - d_1^2).v.n.dt$$

and let a new fish enter the beam each time the integral reaches a new integer value. This should not happen at regular intervals, because in nature

i. the density n is not uniform

ii. individual motions make v vary.

The simple approach is to define n as gaussian random variable with programmable mean and deviation. When the fish is inside the beam, we detect an echo whose receiver output power we compute as:

$$C = B \; S_0 \; K_0 \; T \; R^{-4} \; e^{-2\alpha R}$$

$B = b_1 \; b_2$, where B is the system directional factor, b_1 the transmitting and b_2 the receiving directional factor. The axial source level S_0 and the axial receiver sensitivity K_0 are programmed for a certain transducer and will not change as the fish passes through the beam. We allow each fish its individual target strength T drawn from a stochastic ensemble. The total aggregation is characterized by a certain average target strength and a mean deviation. Since we want to give these parameters in decibels the underlying distribution becomes somewhat special. Target strength is not considered to change appreciably through the beam, a typical fish passing through the beam is thought to move at a constant depth d and along a straight line such that its minimum distance

from the transducer occurs at an angle θ with the beam axis.

Thus the range varies

$$\frac{d}{\cos \theta_1} \leq R \leq \frac{d}{\cos \theta_0}$$

while the fish 'travels'

$$\ell = 2d \, (\tan^2\theta_0 - \tan^2\theta_1)^{1/2}$$

We assume the depth d to be a random variable, uniformly distributed between d_1 and d_2. Also, the angle θ, is considered random with a uniform distribution between 0 and θ_0. When the fish enters the beam we assign appropriate values to d and θ_1. As time passes, we obtain the fish's position by

$$x = \int_{t_0}^{t} v \, dt$$

Interpolation gives an approximate range

$$R = \frac{d}{\cos\theta_1} + \left(\frac{2x}{\ell} - 1\right)^2 \left(\frac{d}{\cos\theta_0} - \frac{d}{\cos\theta_1}\right)$$

Making the calculations this way lets v change while fish pass through the beam. When χ exceeds ℓ, the fish has left the beam and is forgotten. The system directional factor B also changes as the fish passes through the beam. It depends rather strongly upon the angle θ, falling from 1 at $\theta = 0$ to some B_0 at $\theta = \theta_1$, the value when the fish is at position χ, is found by interpolation.

$$B = 1 - (\theta_1/\theta_2)^2(1-B_0)-((2x/\ell)-1)^2(1-B_0-(\theta_1/\theta_0)^2(1-B_0))$$

THE BIOSONICS DUAL-BEAM TARGET STRENGTH MEASUREMENT SYSTEM

by

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1. INTRODUCTION

The most commonly used acoustic assessment technique is echo-integration. It has been shown both experimentally and theoretically that the average integrated acoustic intensity scattered from a collection of fish is proportional to the average density of the fish. The constant of proportionality depends on the parameters of the acoustic system and the average backscattering cross-section for individual fish in the population. Because the latter parameter is so important much work has been done to determine its average value as a function of fish type and size and of acoustic frequency.

Fish target strength studies fall into two categories, controlled experiments and in situ measurements. In the former, the fish are confined, sometimes individual fish are suspended on a rigid structure and detailed measurements as a function of fish orientation and acoustic frequency are made. Another approach is to take measurements on individual or multiple fish confined in a pen. The results of such controlled experiments are often expressed in a regression formula relating individual scattered target strength to fish length and acoustic frequency. Although such measurements have provided much useful information on the acoustic properties of various marine organisms, they do not always provide the kind of information needed for acoustic biomass assessment.

In particular, the use of results from controlled experiments requires a knowledge of the species composition and size distribution of the scatterers being assessed. There is also uncertainty about the degree of correlation between the acoustic properties of free-swimming fish and those artificially confined. At the 1979 meeting on Hydroacoustical Methods for the Estimation of Marine Fish Populations, a number of authors pointed to problems with using target strength measurements obtained in controlled experiments for application to free swimming fish populations (Harden Jones and Scholes) (Hawkins) (Foote). The Advisory Committee on Marine Resources Research (ACMRR) for the Food and Agriculture Organisation of the United Nations (FAO) has voiced a similar concern.

The alternative to controlled measurements is to extract the acoustic size of the individual fish from the acoustic returns in situ. In addition to providing the information needed for scaling the output of an echo-integrator used for abundance estimation, in situ techniques can provide data on the length distribution of the individual fish in the population.

The commonly used system for fisheries assessment has a single transducer for both transmitting and receiving the acoustic signals. The signal level of a fish echo detected by a single-beam transducer depends on the acoustic reflecting properties of the

fish, its position in the acoustic beam, and system parameters. When the signals are amplified by an echo-sounder at a time-varied-gain (TVG) of 40 logR + 2 αR, this relationship becomes,

$$u^2 = kb^2(\theta,\phi)\sigma_{bs}$$

where u = echo-sounder output

$b^2(\theta,\phi)$ = acoustic system's two-way beam pattern function

σ_{bs} = backscattering cross-section of the fish

k = scale factor determined during calibration

Target strength (TS) and backscattering cross-section σ_{bs} are related by TS = 10 $\log_{10}$ (σ_{bs}). To obtain the backscattering cross-section or target strength statistics from the received echoes of single targets, the effects of the scale factor k, and the beam pattern function $b^2(\theta,\phi)$ must be removed from the received single target intensities. The scale factor can be removed in a conceptually straightforward manner. With single beam acoustic systems there is no direct way of separating out the effect of the beam pattern, $b(\theta,\phi)$, from the backscattering cross-section σ_{bs}. There are some indirect techniques which use statistical methods to extract the average effect of the beam pattern from a collection of single fish intensities (Craig and Forbes, 1969) (Robinson, 1978) (Ehrenberg et al., 1981). However, these techniques do not work very well in all cases of interest.

The beam pattern factor can be directly removed from the single fish echo-intensity using multi-beam techniques; of these the dual-beam method is the simplest for accomplishing this process (Ehrenberg 1974, 1978 and Traynor and Ehrenberg 1979). Some typical beam patterns for a dual-beam system operating at 105 kHz are shown in Figure 1. The acoustic signal is transmitted from the narrow beam transducer and is received on both the narrow and wide beam simultaneously. The system is calibrated such that the outputs for the narrow and wide beam channels are equal for an on-axis target. Under these conditions, and assuming ideal time-varied-gain characteristics, the narrow and wide beam echo-intensities for a single fish at angular coordinates θ and φ are

$$I_n = kb_n^2(\theta,\phi)\sigma_{bs}$$

$$I_w = kb_n(\theta,\phi)b_w(\theta,\phi)\sigma_{bs}$$

where k is a constant, $b_n(\theta,\phi)$ and $b_w(\theta,\phi)$ are the beam patterns for the narrow and wide beam transducers, respectively, and σ_{bs} is the backscattering cross-section for the fish. The ratio of the two intensities produces

$$I_n/I_w = b_n(\theta,\phi)/bw(\theta,\phi)$$

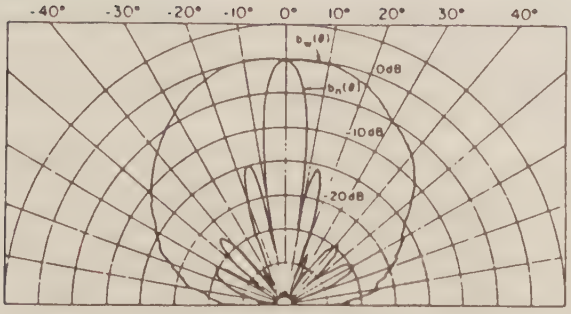

Figure 1. Beam patterns for the 105 kHz dual-beam transducer

There is a one-to-one relationship between the ratio, $b_n(\theta,\phi)/b_w(\theta,\phi)$, and the narrow beam pattern, $b_n(\theta,\phi)$. Using this relationship, the narrow beam pattern is extracted from the intensity ratio. If the wide beam transducer is flat over the main lobe of the narrow beam (i.e. $b_w(\theta,\phi) \simeq 1$), the ratio of I_n to I_w directly gives the narrow beam pattern. This choice of narrow and wide beam patterns may not be optimum with respect to the effect of noise on the system.

The BioSonics Dual-Beam System measures σ_{bs} values of individual fish according to the above principles, it consists of a dual-beam transducer, a Model 101 Echo-Sounder with dual receivers, a Dual-Beam Processor, a microcomputer, and a Target Strength computer program. A Dual-Beam Processor isolates and records single fish echo data received on the narrow and wide beam transducer elements. The Target Strength computer program processes these data to compute the individual σ_{bs} values and compile statistics on σ_{bs}.

In the following sections the Dual-Beam Processor and Target Strength program are described. They can be used for any acoustic frequency.

2. DUAL-BEAM PROCESSOR

Hardware Description

The BioSonics Dual-Beam Processor is shown in Figure 2. The unit contains two microprocessors: an Intel 3000 bit-slice processor for high-speed, realtime processing and a Zilog Z80 microprocessor for input-output. Both random-access-memory (RAM) and read-only-memory (ROM) are incorporated into the processor design. A 16-character keyboard is used to enter parameters such as noise threshold, starting depth and single-echo recognition parameters. An alpha-numeric display permits the operator to monitor parameters being entered and displays prompts and error messages.

Figure 2. BioSonics Dual-Beam Processor

The output data for each detected echo: narrow and wide beam pulse durations, ping number and narrow and wide echo amplitudes, fish depth and echo classification (single, multiple) are recorded on a digital cassette. This information can also be supplied in real time to a computer via a RS232 serial port. Narrow and wide beam envelope detected inputs to the processor are digitized by 12 bit ADC at a 15 kHz rate. Other inputs are a "sync" to synchronize the processor with the echo-sounder and a "bottom detect" that enables the processor to track an external bottom signal. When an external bottom detect signal is not provided by the echo-sounder, the processor can be switched to an internal bottom detect mode. In this mode, an internal bottom detect signal is generated when the narrow beam signal exceeds a threshold set by the operator. A manual bottom tracking adjustment is also available which allows the operator to manually set, using a potentiometer, the depth at which processing is terminated. A "monitor" output channel can be connected to an oscilloscope to indicate the location of isolated echoes and the bottom depth. Single target detections are also indicated by a light emitting diode (LED) display. A LED is also used to indicate the timing of the sync pulse. Automatic bottom tracking loss of track is indicated on the alpha-numeric display and by an audio alarm. The alarm can be disabled by the operator.

Software Description

The main functions carried out by the processor's software are single echo detection, echo parameter determination, and bottom tracking. Each of these functions will be described separately.

A typical detected signal for a single fish echo is shown in Figure 3. The single echo detection software processes all echoes whose amplitudes exceed the noise threshold set by the operator. When an echo exceeds the threshold, the half and eighth amplitude

pulse duration, τ_1 and τ_2, are measured and compared with the range of pulse durations supplied by the operator. If the half amplitude pulse duration, τ_1, is less than the specified minimum pulse duration, the signal is assumed to be a noise spike and is ignored. When the measured half amplitude pulse duration is between the specified minimum and maximum values for τ_1 and the eighth amplitude pulse duration is less than the maximum value of τ_2, the echo parameters are recorded and the echo is labelled as a single echo. If the half amplitude pulse duration is greater than the minimum specified value of τ_1, and if either τ_1 or τ_2 exceed their corresponding maximum limits, the pulse is accepted and labelled as a multiple target. By recording the parameters for the echoes that do not satisfy all the single echo criteria, the operator has the flexibility to change the echo acceptance criteria during post processing of the data.

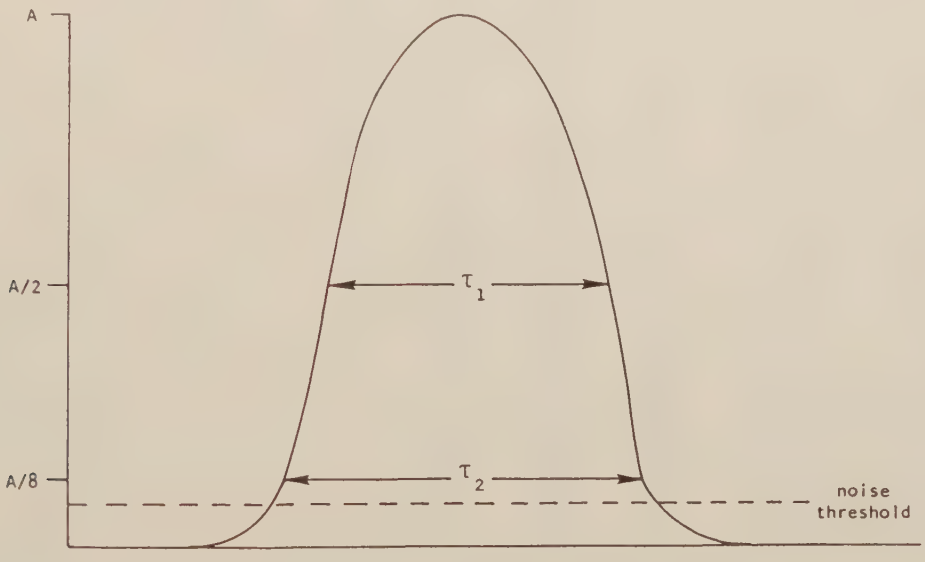

Figure 3. Pulse shape for a detected single fish echo

The parameters recorded (or sent directly out of the RS232 serial port) are the channel 1 and channel 2 echo amplitude, the channel 1 and channel 2 half amplitude pulse durations, the ping number, the target depth and the single/multiple target classification code. An example of the data produced is shown in Figure 4.

Threshold, mV = .30E+03
Bottom Threshold, mV = .15E+04
Max -18 dB Pulse Duration, ms = .5416E+00
Min - 3 dB Pulse Duration, ms = .1980E+00
Max - 3 dB Pulse Duration, ms = .4669E+00
Bottom Window Size in metres = .1000E+01
Start Depth in metres = .1000E+01

Ping No.	Amp 1 mV	Amp 2 mV	Depth M	PW 1 ms	PW 2 ms	Classification
816	622.200	590.480	7.550	.267	.267	S
817	627.080	649.040	7.600	.200	.333	S
818	646.600	675.880	7.550	.267	.270	S
819	405.040	468.480	7.600	.267	.200	S
820	588.040	732.000	7.600	.267	.267	S
821	1041.880	1159.000	7.550	.267	.267	S
822	1551.840	1620.160	7.600	.200	.200	S
823	1676.280	1654.320	7.600	.267	.267	S
824	1093.120	1171.200	7.600	.200	.267	S
825	844.240	1002.840	7.600	.267	.267	S
826	936.960	1307.840	7.550	.200	.333	S
827	1115.080	1922.720	7.550	.200	.200	S
828	1373.720	2213.080	7.550	.267	.267	S
829	973.560	2027.640	7.550	.267	.267	S
830	900.360	1698.240	7.600	.267	.267	S
831	954.040	1637.240	7.550	.267	.267	S
832	966.240	1571.360	7.600	.267	.267	S
833	895.480	1373.720	7.550	.267	.267	S
834	673.440	1141.920	7.600	.267	.267	S
835	929.640	1493.280	7.600	.267	.267	S
836	1132.160	1424.960	7.600	.200	.333	S
837	1112.640	1483.520	7.600	.200	.200	S
838	1190.720	1249.280	7.650	.200	.267	S
839	1332.240	1561.600	7.600	.200	.200	S
840	1627.480	1895.880	7.600	.200	.200	S

Figure 4 Typical output from the dual-beam processor

The automatic bottom tracking software prevents the processor from accepting bottom returns as single fish echoes. It accomplishes this by using a "bottom window" and the external bottom signal or the software generated bottom location determined from narrow channel input and the operator selected bottom threshold. The location of the bottom is continually updated provided the bottom location is within the window centred on the previous ping's bottom location. Processing is terminated at the depth corresponding to the leading edge of the bottom window. If the bottom occurs outside the bottom window, the data from the ping are rejected, a "lost track" message is displayed and an alarm is sounded (if enabled). Bottom tracking can be switched from the automatic to manual tracking mode at any time.

Target Strength Computer Program

There are two general approaches that can be used in developing a modern processing system such as the dual-beam processor. One is to have the unit do all the processing from signal input to final output. The main disadvantage of this approach is that it does not usually provide flexibility needed to customize the processor for different

applications. The second approach is to break the processing task into two operations: a high speed dedicated processor for data acquisition and preprocessing, and a slower, more versatile, easily programmable post processor (such as a microcomputer). We have chosen this second approach. The data from the Dual-Beam Processor (narrow and wide echo amplitude and pulse duration, ping number, depth and classification) are transferred to the post processor over a standard RS232 serial link.

The post processor software can easily be developed/modified using a higher level language such as BASIC, FORTRAN and PASCAL and data can be stored or displayed in a variety of ways. For example, the output can be written to a disk file or printed out, or it can be plotted out on a CRT or flatbed plotter if suitable hardware and graphics software are available.

The Target Strength FORTRAN program which processes the serial output of the Dual-Beam Processor and obtains target strength and backscattering cross-section statistics is available from BioSonics. This program computes the mean and variance of the single fish backscattering cross-section (σ_{bs}) and target strength and it outputs the target strength histogram for individual depth layers. It also allows the operator to change the narrow and/or wide channel gains, provide a TVG correction for data from an echo-sounder with non ideal TVG, select the range of beam angles for which echoes are processed, select a smaller depth range than that used for collecting data, and change the single echo acceptance criteria. A typical output from the target strength program is shown in Figure 5. Since the program is written in a higher level language, it can be easily changed. For example, the software can be easily modified to reconfigure a dual-beam processor to an echo-counter with a controlled beam angle transducer.

3. APPLICATIONS

This section contains sample data from recent dual-beam acoustic surveys of sockeye salmon, rainbow smelt and other fish in North American lakes. These data were collected using a dual-beam transducer mounted in a towed fin and processed with a BioSonics Dual-Beam Processor. During one of the acoustic surveys, the sockeye salmon were also fished with a trawl. Figure 6 shows the relationship of the length frequency distribution of the netted fish as compared to the target strength distribution of the acoustically sampled fish. Length data obtained from the trawl sample has been converted to target strength using a regression relationship derived by Love (1971).

Another survey was done in a lake in which there was an aggregation of small fish in the upper layer of water with larger fish dispersed below. Figure 7 shows a plot of the dual-beam output for this survey. The small fish of target strength about -61 dB, which corresponds to 1.4 cm long fish, were distributed in the upper part of the water above the thermocline. Larger fish were distributed below the thermocline. Results of trawl fishing show that 0-year juvenile rainbow smelt were in the upper layer, while adult rainbow smelt and other large fish were caught in deeper water.

Total Number of Recorded Targets = 5205
Number of Target Used for Statistics = 2170
Average Backscattering Cross-Section = .1623E-04 in dB = -47.8960
Backscattering Cross-Section Std Dev = .5530E-04
Average Target Strength in dB = -50.5113
Target Strength Std Dev in dB = 4.1650

TS	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	Depth (metres) at the start of each 4 m deep layer.
-65.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
-63.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
-61.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	
-59.0	1.0	15.0	11.0	8.0	8.0	11.0	4.0	1.0	0.0	0.0	
-57.0	4.0	45.0	27.0	17.0	19.0	13.0	4.0	2.0	0.0	0.0	
-55.0	7.0	70.0	60.0	36.0	41.0	18.0	10.0	0.0	0.0	0.0	
-53.0	5.0	118.0	104.0	76.0	34.0	17.0	12.0	1.0	0.0	0.0	
-51.0	7.0	91.0	106.0	84.0	81.0	38.0	12.0	1.0	0.0	0.0	
-49.0	1.0	45.0	122.0	83.0	103.0	43.0	6.0	1.0	0.0	0.0	
-47.0	2.0	14.0	79.0	61.0	70.0	30.0	7.0	2.0	0.0	0.0	
-45.0	1.0	6.0	36.0	31.0	44.0	21.0	4.0	6.0	0.0	0.0	
-43.0	0.0	1.0	19.0	13.0	25.0	12.0	2.0	6.0	0.0	0.0	
-41.0	0.0	0.0	2.0	3.0	9.0	2.0	2.0	1.0	0.0	0.0	
-39.0	0.0	1.0	1.0	1.0	5.0	6.0	0.0	1.0	0.0	0.0	
-37.0	0.0	2.0	0.0	1.0	4.0	1.0	1.0	0.0	0.0	0.0	
-35.0	0.0	2.0	1.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	
-33.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
-31.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	

Figure 5 Tabular form of output of dual-beam processor. Program giving T.S. histogram for specified depth layers

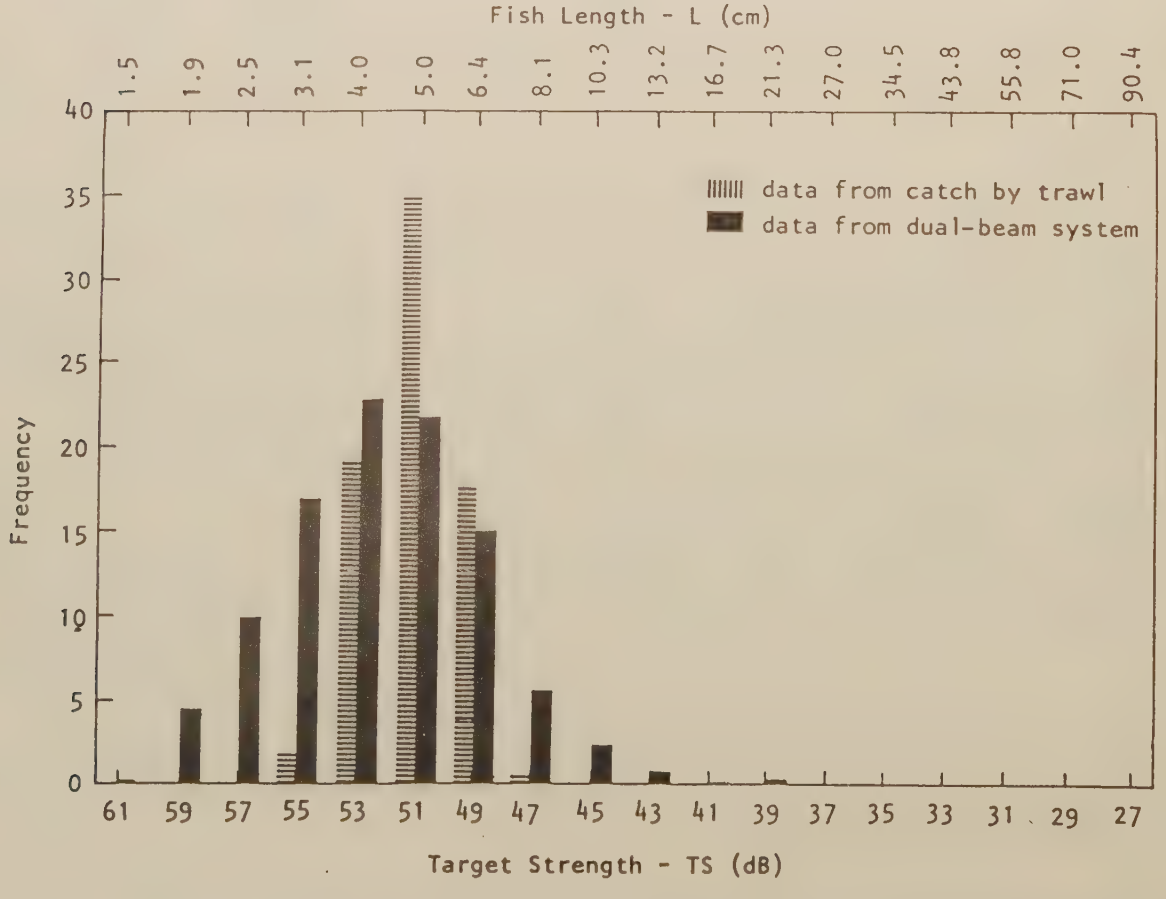

Figure 6 Target strength vs. fish length frequency distribution

4. CONCLUSIONS

The BioSonics Dual-Beam System provides fisheries biologists and fisheries management agencies with a technique for collecting and analyzing in situ acoustic size information for a fish population. Information obtained with this system will not only improve the accuracy of acoustic assessment surveys but will also provide valuable information on physical size of the fish in the population.

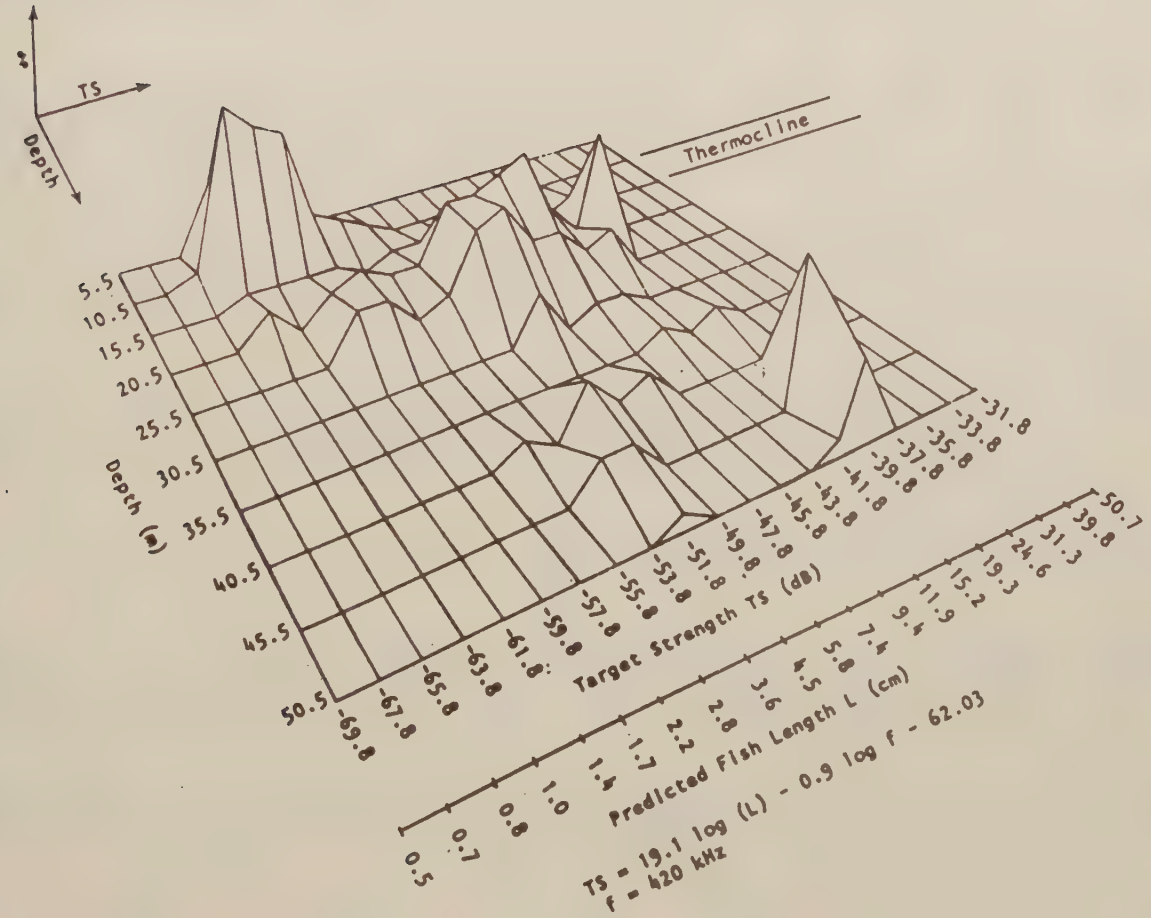

Figure 7. Target strength distribution by depth for individual fish detected along a transect of a North American lake. Equation by Love (1971) relates target strengths to predicted fish lengths

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"AGENOR"
A DIGITAL ECHO INTEGRATION SYSTEM FOR FISHERIES RESEARCH 1/

R. Person*, E. Marshal#, T. Terre#, J. Berthe*

1. INTRODUCTION

Echo integration is now a widely used technique in fisheries management in spite of numerous problems that are encountered in its use. New, and more suitable equipments are being designed. Microcomputer based instruments are portable and well suited to real-time fisheries data collection. The echo-integrator described here results from the meeting of scientists using echo-integration for many years (ORSTOM) and electronics and computer specialists familiar with data collection systems. The same instrument can be used to estimate the total biomass in a small lake aboard small boats as well as in the open sea aboard oceanographic vessels. AGENOR is a versatile instrument which can operate alone or be integrated in a more complex data system.

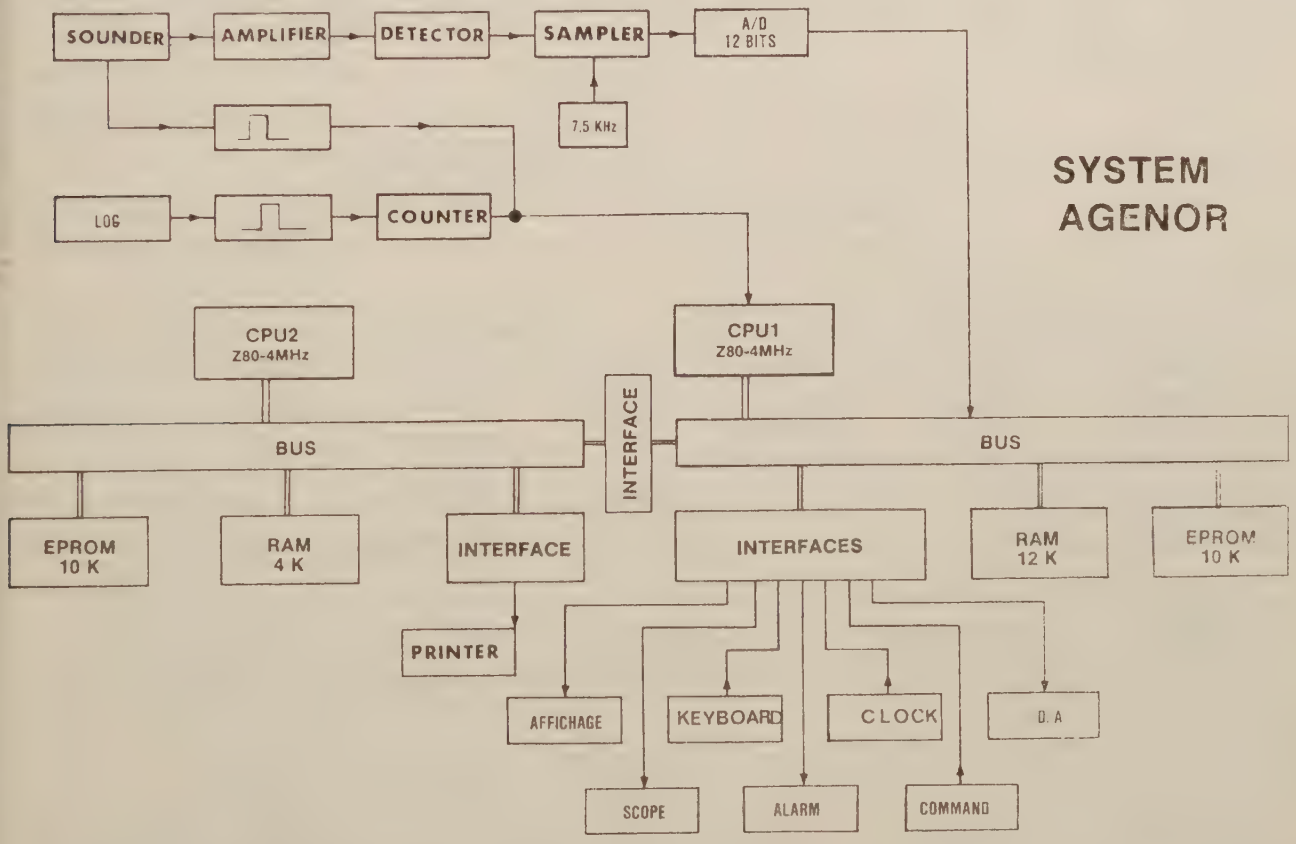

Figure 1

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1/ Modification and translation of Contribution No. 17 of the ICES/FAO Symposium on Fisheries Acoustics by the same authors, entitled: Système d'écho integration numérique pour l'évolution des stocks "AGENOR".

2. DESCRIPTION

2.1 Configuration

The normal AGENOR system configuration is shown in Fig. 1. Analog signals from the echo-sounder are amplified and then detected before digitizing. The digital processing is supported by two Z 80 microprocessors running at 4 MHz (Figs. 2 and 3).

The central processor 1 controls:

i) the analog to digital converter

ii) digital sample storage

iii) automatic or manual bottom tracking

iv) the different interfaces between AGENOR and the operator (Keyboard, display switches etc).

Digital samples are processed by this unit and the results are sent to unit 2 at the end of each sequence. A software routine detects eventual programming errors, a check of memory and principal functions is performed when the "TEST" routine is activated.

Data coming from unit 1 are processed by the central unit 2, then results are sent to the front panel printer and also to the RS232 port in ASCII format. This output can be used to send integrated data to a computer or to a digital storage device.

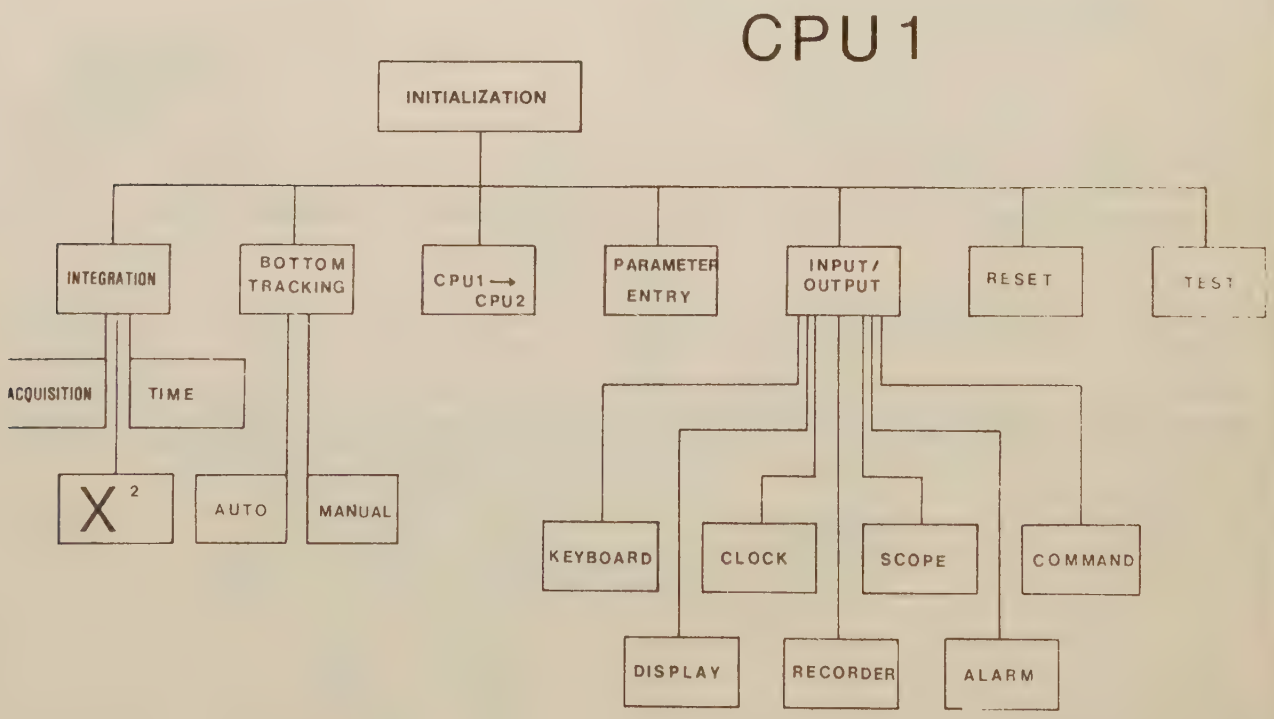

Figure 2

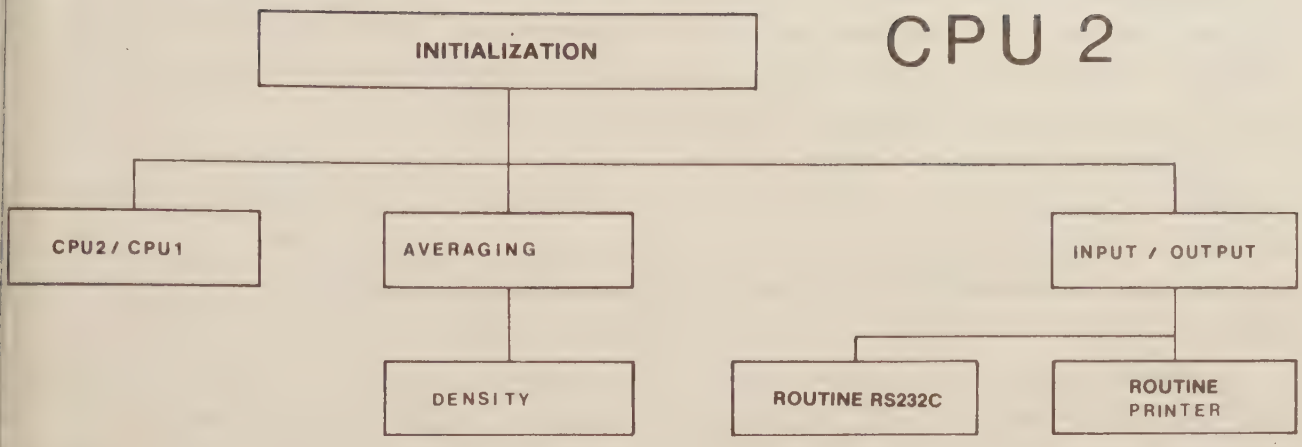

Figure 3

2.2 Input-Ouput specifications

AGENOR can be connected to different echo-sounders. In the normal system, the incoming signal frequency may be between 10 and 50 kHz but this can be easily changed to higher frequencies. The dynamic range of input signals is 60 dB.

The input amplifier is switched between - 12 dB and 29 dB by steps of 3 dB. Any input amplifier saturation is detected and signalled to the operator by a red, light emitting diode (LED).

The synchronisation circuit of AGENOR is driven by the leading edge of a positive or negative pulse. A capacitive coupling allows for a synchronisation pulse that starts at voltages other than zero and a remote switch can be used. The system can also receive pulses from the ship's log.

Mounted on the front panel printer is an alpha-numeric thermal printer (Model APP-20 manufactured by Datel System, Inc.) with 20 characters per line. All information sent to the printer also goes to the RS232 port. This port can be replaced by an IEEE 488 interface.

An analog output of the integrated signal in all layers, starting from the surface, is available for each ping, this provides a convenient way to control the integration on an analog recorder.

3. OPERATION

3.1 Main functions

The detected signal from the echo-sounder is sampled every 133.3 ms which is equivalent to range increments of 0.1 metre when the speed of acoustic waves is 1500 metres/second. Sampled voltages are converted to 12 bit digital words by the analog to digital converter, the last significant bit is 2.5 mV. Each ping at the SYNC input resets the sample clock. Voltages less than the threshold are set to zero. Each sampled voltage is squared by reading a table.

The bottom determination and tracking function have been particularly well elaborated, this assists in the distinction between echoes from fish and those from the bottom. An algorithm based on experience is used whereby the maximum value of signal inside an adjustable width window is determined and this window is centred on the previous BOTTOM value. The maximum must be greater than a BOTTOM threshold.

At the first occurrence of the maximum value it is multiplied by 3/4 and the resultant is taken as the new BOTTOM value. This position is much more stable than the maximum one which is affected by the bottom topography, the ship's pitch and roll, etc. A bottom width parameter is entered which corresponds to the leading edge of the bottom pulse, the bottom value minus Bottom width gives the limit of integration.

In manual bottom tracking, the Bottom value is set by the manual control dial on the front panel, the window output, (Fig. 4) is intended for oscilloscope monitoring. Normally, as soon as the bottom pulse is inside the window, the automatic bottom tracking mode is selected, but manual control is convenient in some circumstances eg rapidly increasing or decreasing bottom depth, high density fish schools near the bottom, etc.

In the automatic bottom tracking mode, the ping is eliminated when no maximum greater than the threshold value is found inside the window. An allowed number of bottom losses is programmed. When this number is reached, the window is automatically centred

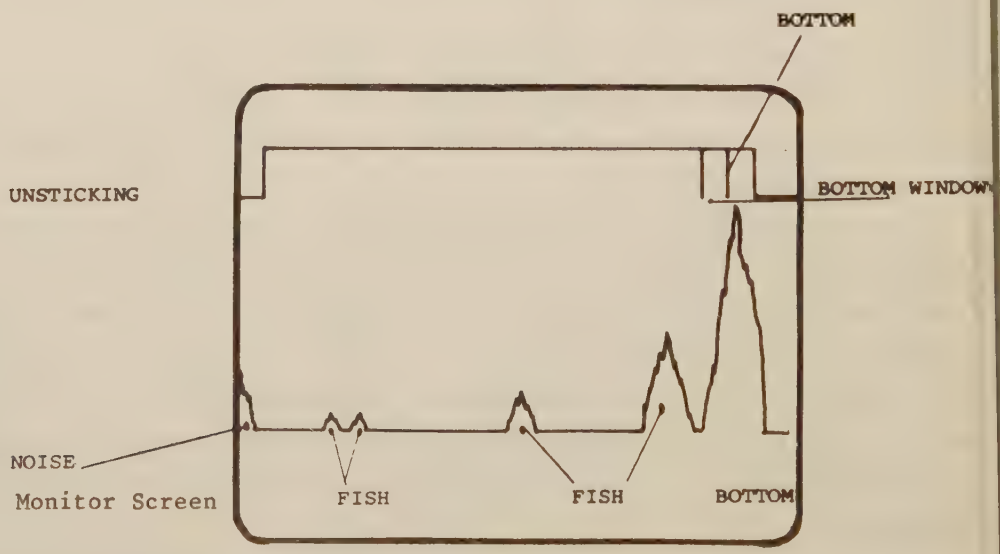

Figure 4 Oscilloscope Monitor Screen

on the lower limit of the layer immediately above . An alarm is sent to the operator and integration is continued with this new limit. This method avoids the loss of too many detections of pelagic fish.

3.2 Parameter Entry

Real time data analysis must work in very varied situations. A special feature of AGENOR is that the operator can, at any time, enter parameters relevant to the current acoustic survey. Parameters are entered via the front panel keyboard, before the survey is undertaken, but at any time they can be modified and the running sequence can be completed or stopped. Only the sequence following the modification is affected. Data collection continues while parameters are modified. Entered parameters are printed out on the front panel printer and the RS232 port when they are modified.

4. INTEGRATOR SOFTWARE

The major section of the software calculates the average acoustic target density by unit surface Rs_j or volume Rv_j for each layer during a sequence of Ne pings.

For the layer j the number of samples is

$$N_J = \sum_{k=1}^{Ne} N_{j,k}$$

$N_{j,k}$ is the total number of samples in the layer j for the ping k.

The average acoustic target densities are:

$$Rs_j = \frac{1}{10} \cdot \frac{1}{Ne} \cdot A \cdot B_j \cdot \sum_{i=1}^{N_j} \sum_{k=1}^{Ne} V^2_{i,j,k}$$

and

$$R_{vj} = A \cdot B_J \cdot \frac{1}{N_j} \sum_{i=1}^{N_J} \sum_{k=1}^{Ne} V^2_{i,j,k}$$

where

$V^2_{i,j,k}$: squared instantaneous sampled voltage for increment i in the interval j and the ping k.

A : an overall scale constant derived from a combination of factors dependent on the acoustic hardware, the speed of acoustic waves in water and the average backscattering cross-section of the fish. It relates the sum of squared voltages to the fish densities. The constant has units of kg/m^3 $volt^2$, or, $fish/m^3$ $volts^2$.

B : A non-dimensional scale factor which corrects for any variations in the time-varying gain of the echo-sounder.

The Rs_j values are divided by ten to account for the sampling rate, 10 samples per metre.

All these values are expressed in decimal units. They can be relative or absolute, depending on how the characteristics of the system are determined.

The instrument also calculates:

i) the sum of integrated values for all the layers referred to the surface

$$S = \sum_{j=1}^{N} Rs_j$$

where N is the number of layers.

ii) the average of the acoustic target densities for all the layers referred to the surface

$$M = \frac{\sum_{j=1}^{N} Rs_j}{\sum_{j=1}^{N} N_j}$$

iii) the total number of pings in each sequence Ne

iv) the total number of samples for each layer which is directly proportional to average thickness ($\bar{e}$) of the layer depending on acoustic wave speed (c). If c = 1500 m/s, then

$$\bar{e} = \frac{N_j}{Ne}$$

v) the total number of samples greater than the threshold for each layer

$$N_j^+ = N_j \geq \text{seuil (threshold)}$$

this number, compared to N_j, gives the occupation rate of the layer, a useful index to calculate the volume of a fish school. When examined, it is easy to detect from it the integration of noise, or the bottom echo. An example of the printout is shown in Figure 5.

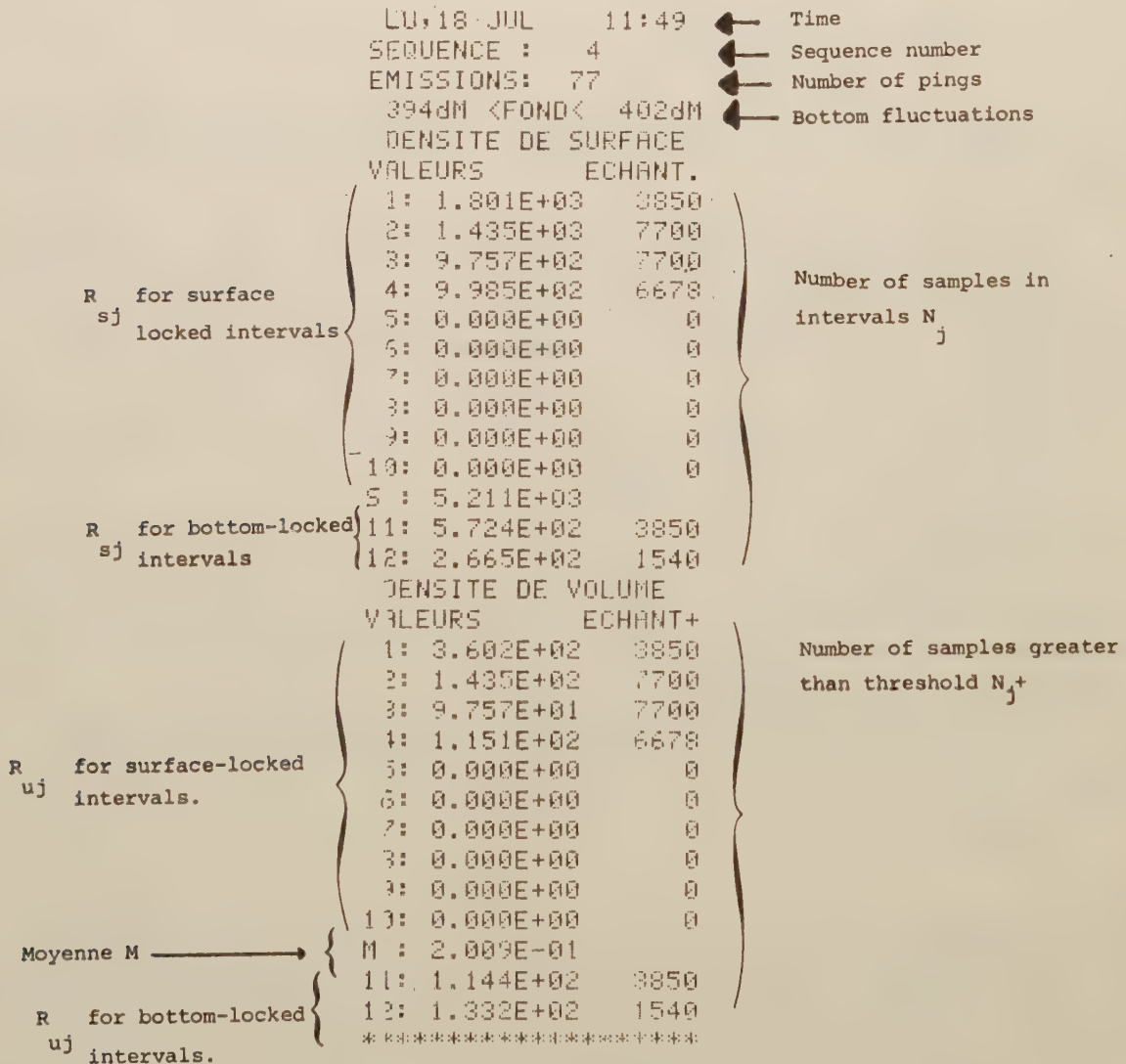

Figure 5 AGENOR printout

5. OPERATION OF THE AGENOR SYSTEM

When switching on, the prompt 'AGENOR VERS X - 0' appears. The operator must select the 'CHGT PARAM' mode, then enter the parameters relevant to the survey to be conducted.

5.1 Parameter Change mode ('CHGT PARAM')

When the Parameter Change mode is selected, the first line of parameters appears on the screen and a cursor is displayed. It can be decremented or incremented by keys ← and →. The operator enters the desired new value. Key ↓ stores the current line; the next line of parameters then appears on the screen. Only selected parameters have to be entered but all are displayed. When the last line of parameters is validated, the first line appears again.

The programmable parameters are listed below

1 - SE Sequence number (0 - 9999): this is automatically incremented with each sequence. It is the user's reference.

2 - EM Number of pings (0 - 9999): the number of pings in each sequence.

3 - MN Length of the sequence (0 - 9999): the number of minutes in each sequence.

4 - ML Log number (0 - 256): the number of 1/10 miles sailed over each sequence.

5 - SL Threshold (0 - 9999 mV). When a sample is less than the threshold, it is read as Ø. The threshold voltage is referred to the analog-to-digital converter. To choose a threshold value the operator can look at the detected signal on an oscilloscope.

6 - FN Window (0 - 9999 ms): the time interval over which the automatic bottom tracking operates.

7 - DS: surface offset (0 - 9999 dm): the samples read in this interval are stored as Ø.

8 - DF Unsticking (0 - 9999 dm). A distance interval above the bottom over which integration is stopped in order to prevent integration of the bottom echo.

9 - PF Number of bottom echo losses (0 - 256). In automatic bottom tracking, the number of pings eliminated before alarm setting.

10 - MA Acquisition mode (1, 2 or 3)
In mode 1, the sequence is stopped and a new one is repeated when the number of pings EM is reached.
In mode 2: the sequences are repeated every MN minutes
In mode 3: the sequence is stopped when the log number is reached.

11 - NB Number of ranges (1 to 10). The number of neighbouring range intervals referred to the surface for which echo signals will be integrated.

12 - A - Constant A. It is initialized to 1000.

13 - Tn: the end of each interval (0 - 9999 dm). The range interval 11 and 12 are bottom locked. They are defined by their thickness (Figure 6).

14 - Bn: B constant for each interval. They are preset to 1000.

If no consistent value is entered, the prompt "ERREUR XX" appears on the screen. XX is a code number error.

5.2 'PAUSE' mode

When the 'pause' mode is selected, data collection is stopped. If a sequence is running, collected data are printed. This mode is very useful to adjust the system before the survey begins. The sequence number, the last automatic bottom value and the manual bottom value given by the manual control dial are displayed. The operator can observe on an oscilloscope monitor the detected signal from the echo-sounder and the bottom window (see Figure 6). The bottom echo must be placed in the bottom window,

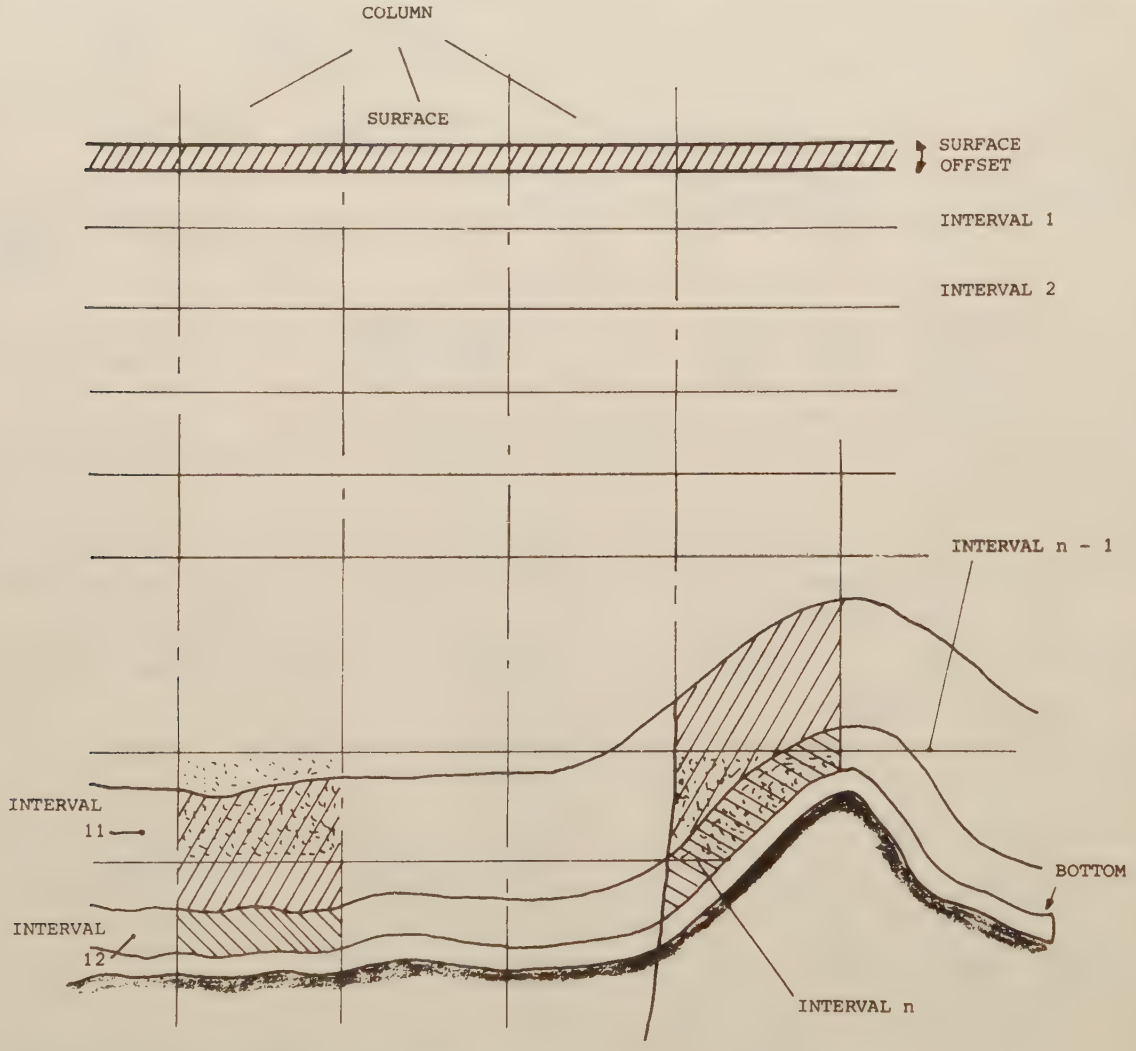

Figure 6 Surface-Locked and Bottom-Locked Intervals

before the operator uses the 'CALAGE' button. This gives the initial value for automatic bottom tracking.

5.3 'ACQUISITION' mode

When the acquisition mode is selected, data processing is to begin. Automatic bottom tracking is activated. At the end of each sequence data are printed out. An alarm will occur if no maximum value is found in the bottom window during PF successive pings. The operator must selected the 'PAUSE' mode or the 'CONTROLE FOND' mode to re-initialize the automatic bottom tracking.

5.4 'CONTROLE FOND" mode

This mode is similar to the 'ACQUISITION' mode but the manual bottom tracking is used in place of the automatic tracking, which can also be initialized in this mode.

At any time it is possible to modify any parameter by selecting the 'CHGT-PARAM' mode.

6. DISCUSSION

A small number of the instruments described above have been manufactured. These systems were used during different cruises aboard N.O. THALASSA, N.O. CORIOLIS and N.O. CAPRICORNE in different areas: North Sea, Bay of Biscay, Gulf of Guinea and around Indonesia. Good data were collected and are being prepared for publication.

It is easy to connect the echo-integrator to an echo-sounder and its use on small boats is possible so making it useful to laboratories having vessels working in shallow waters and lake.

New external modules are under development. These will extend the capabilities of the AGENOR system. A logger for raw data can be connected. All data above the threshold are recorded on 8" floppy disks to allow complex play-back computations. Another device provided with a faster processor and additional hardware, supports software for the classification of single fish echoes and detailed analysis of schools echoes.

The outstanding feature of the AGENOR is its versatility given by the numerous operator-entered parameters. Its multi-processor conception allows new developments without any change in the basic system.

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THE BIOSONICS MODEL 121 DIGITAL ECHO-INTEGRATOR

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1. INTRODUCTION

The BioSonics Model 121 Digital Echo-Integrator, in conjunction with a scientific echo-sounder, is designed to calculate the total biomass in a surveyed area. A multiple micro-processor design has resulted in an accurate, versatile and easy to operate instrument. Real-time field or laboratory operation is possible. Up to 99 depth interval, surface or bottom-locked, may be analysed. Different thresholds and TVG correction factors may be entered for each depth interval. Three bottom tracking modes are available which may be selected at any time via front panel controls or with the hand-held remote bottom-tracking controls.

The Model 121 is also designed to operate as a data logger with a two channel capability. Raw data are rapidly digitised and stored on a high speed digital magnetic tape, these data can then be analysed via computer in the field or in a laboratory.

Simple integration is not sufficient for most needs. Numerous operator-specified features are required to tailor the data processing and its presentation for the particular survey at hand. The Model 121 Digital Echo-Integrator (DEI) which has evolved from the earlier Model 120, is designed to work with most echo-sounders having good stability and wide dynamic range. It can be used on board a large or small vessel for surveys at sea or on lakes, or as part of a stationary system to assess the stock of migrating fish in a river. Fish, silt plumes, plankton and other acoustic scatterers can be assessed. This unit can be interfaced via its RS232 data output port to a variety of small, inexpensive computers for storage and further processing of integrated data.

2. THE MODEL 121 DIGITAL ECHO-INTEGRATOR: FUNCTIONAL DESCRIPTION

A brief description of the Model 121 is given in this section. Figure 1 shows the front panel, operator controls and I/O devices of this integrator. The operation can be as simple as connecting signal lines to the echo-sounder, turning the power on, and selecting the Run mode. Usually, however, the user will want to take advantage of the instrument's array of programmable features to tailor the operating characteristics to individual survey applications. These features are easy to comprehend and put to practical use. A self-test mode is entered whenever power is applied, or when the unit is manually reset. Vital instrument functions are automatically tested for proper operation by the main micro-processor. Next the DEI "asks" the operator to select Integrator or Data Logger for the main instrument function. The integrator function will be described first followed by a section on the data logger function.

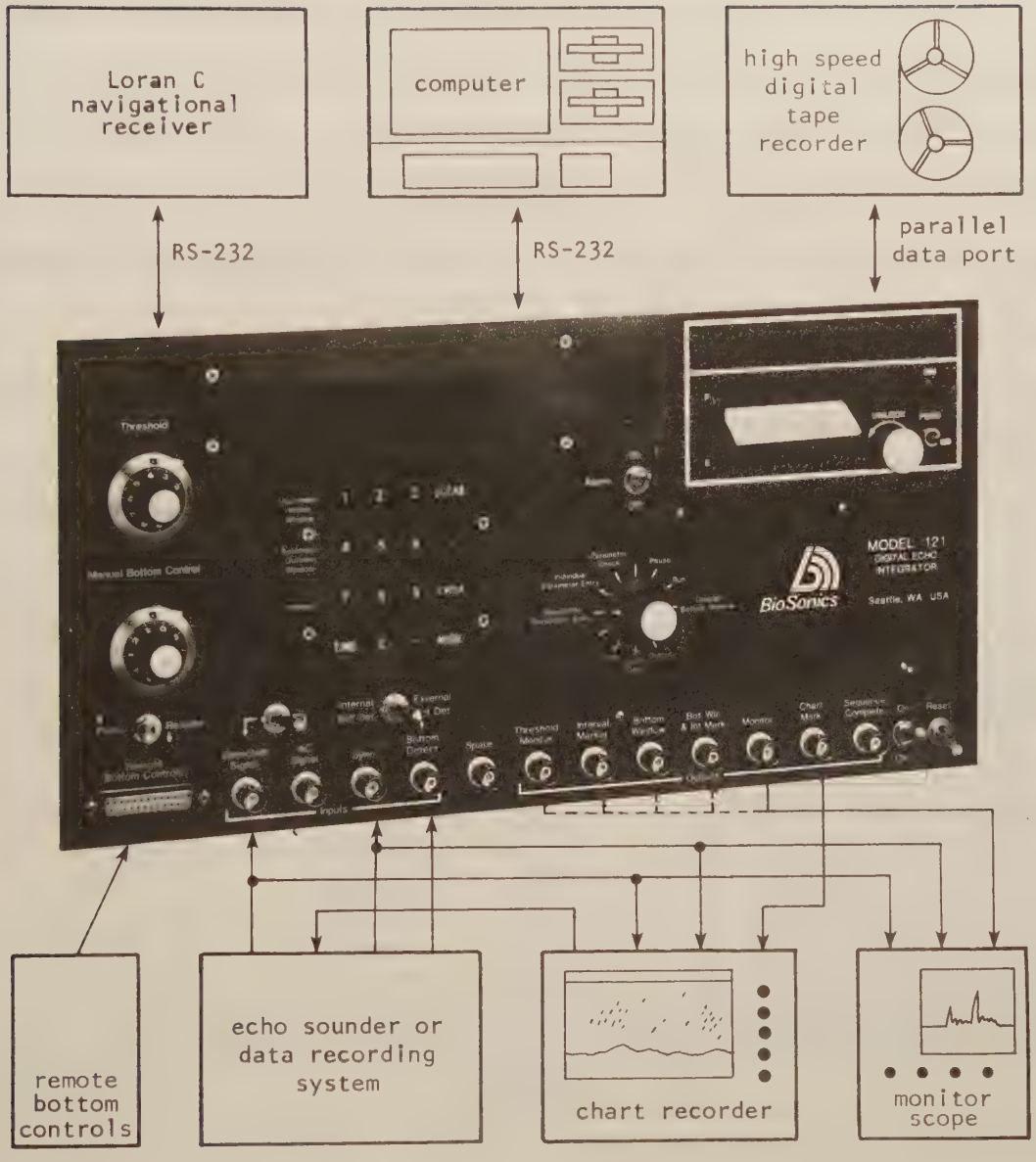


Figure 1. Model 121 Digital Echo Integrator with other system components

2.1 Sequential Parameter Entry

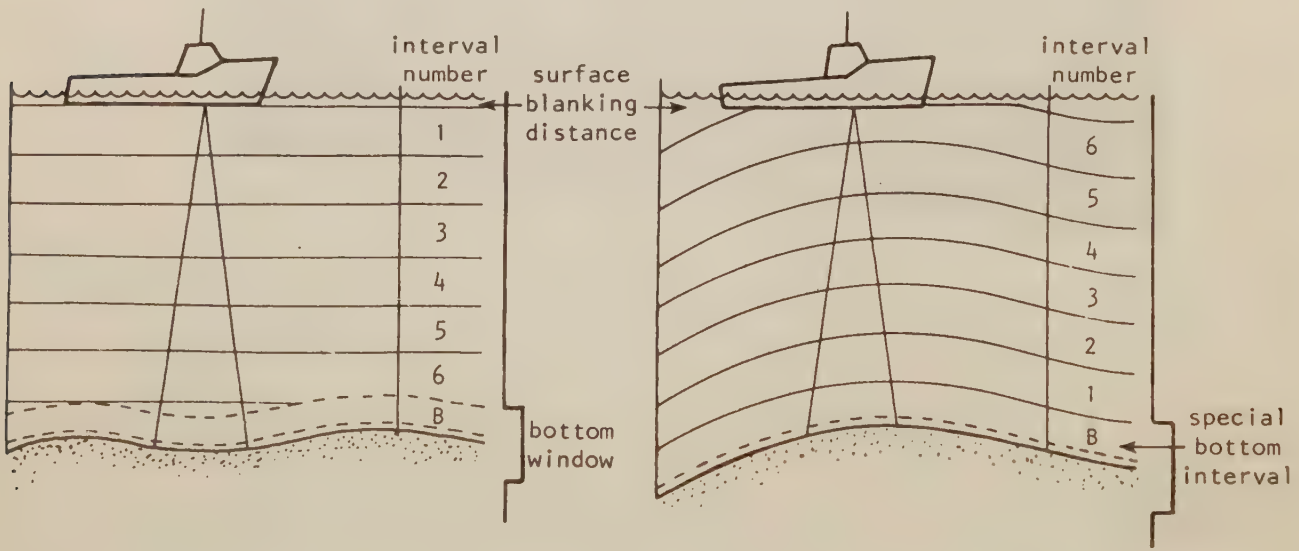
Operators can enter a variety of parameters to configure the instrument to a particular application. Once entered, the desired parameters are retained and need not be re-entered, even after turning the power off. The sequential parameter entry mode may be selected at any time by the operator for entering the following parameters.

Data may be processed for either a time interval, or a set number of pings specified by the operator. Integrated data are output when the number of pings or the specified time interval is concluded. Each data output is called a sequence and they continue until a specified number have occurred, at which time integration stops until further instructions. The specified number of sequences constitutes a file.

An internal clock/calendar may be set by the operator, the time and date are output with each sequence of data. The clock is also used to determine sequences specified by time intervals.

Shortly after an acoustic pulse is transmitted, signals may be present due to the transducer ringing or to surface clutter. Integration of these signals may be avoided by specifying a surface blanking distance (Figure 2).

Integrated data are usually stratified or separated into depth intervals. The operator may specify up to 99 depth intervals in 0.1 metre increments to a maximum of 999.9 metres. Each interval may have an associated threshold voltage. Data below the



Transmission-Locked Bottom-Locked.

Figure 2. Echo-integration in range intervals

threshold are assumed to be noise and are not integrated. A "B" constant multiplier may be entered for each depth interval to compensate for echo-sounder TVG inaccuracies. The value of the B constant may range from .01 to 99. However, when using the BioSonics scientific echo-sounders with their highly accurate TVG, B=1 values can be entered.

In most applications, it is very important that the integrated output does not contain bottom echo data. Part of the bottom tracking method uses a programmed bottom

window, selectable from 1 to 20 metres in 1 metre increments (see Run mode, bottom tracking description for more detail). Regular integration is halted at the leading edge of the bottom window. In addition to the regular transmission-locked intervals (Figure 2) there is a special bottom interval which extends from the leading edge of the bottom window to within the specified distance of the bottom. Normal integrator operation is in a transmission-locked mode in which depth intervals are referenced from the transducer downwards. In the bottom-locked mode, depth intervals are referenced from the bottom upward, beginning at the bottom depth but the surface blanking distance still applies to prevent integration of near-surface noise. One of the bottom tracking modes is accomplished manually by a control with a range scale which can be specified from 10 metres to 1000 metres to provide the correct resolution for the particular survey.

A single 'A' constant multiplier may be specified for all intervals to scale the integrator output to units that are meaningful to the operator, such as fish/m^3 or biomass/m^3. The A constant may range in value from 0.01×10^{-10} to 9.99×10^{10}.

The Model 121 DEI has a panel printer, an RS232 data output port, an RS232 data input port for Loran C navigation and a high speed parallel port for sending data to a digital tape recorder. An operator may independently specify any one of these functions to be on or off.

2.2 Parameter Check and Individual Parameter Entry

It is often necessary to verify, or to provide a permanent record of the entered parameters. The Parameter Check mode of operation will print out all parameters entered by the operator (see Figure 3) and the same information is sent via the RS232 port, or the parallel port. Any single parameter may be changed by entering the Individual Parameter Entry mode of operation. The operator first specifies the parameter, then the new parameter value.

2.3 Run

Upon entering the Run mode, the operator first selects a bottom tracking mode via the keyboard (see next section). Data collection/processing begins immediately. Input data are digitised by a 12-bit, analog-to-digital converter at a 7.45 kHz rate. Data are output when the specified number of pings or the specified time interval is reached. All data are fully buffered to minimise or to prevent the loss of data collection time during data output.

Bottom tracking to prevent integration of bottom signals is very important. To provide flexibility there are three bottom tracking modes. Manual bottom tracking is the simplest method: Here, the operator uses a front panel dial to position the bottom window so that it appears centred about the bottom distance. For this, it is necessary to use a monitor oscilloscope to compare the bottom window with echo-sounder signals. A monitor output signal is available to assist manual bottom tracking. The Automatic 'Outside' Window bottom tracking mode will centre the bottom window around the first detected bottom signal. This mode is useful when rapidly changing bottom depths require a fast response in bottom tracking.

The Automatic 'Within' Window tracking mode only responds to bottom signals that occur within the bottom window, it is useful for situations where large targets or fish schools could trigger a false bottom detection.

The bottom tracking mode, manual bottom distance and the most recent automatic bottom distance are displayed on the front panel during the run mode. Display prompts and an audible alarm alert the operator when the bottom signal is lost or occurs outside the bottom window. The operator may select either an external bottom detected signal (if available) or an internally generated bottom detected signal, the internal bottom detect signal is generated when the input data signal exceeds a threshold which is variable via a front panel control.

2.4 Change Bottom Window

It is sometimes necessary to change the bottom window size during data collection to optimise bottom tracking. The Change Bottom Window mode may be entered at any time to allow rapid alteration of the bottom window size.

2.5 Output

Data output is via a panel-mounted printer or to a computer via the RS232 port or both. Data are output upon occurrence of any one of the following conditions:

i. A sequence is completed as specified by either a time interval or number of pings.

ii. The output mode is selected (manually).

iii. An output trigger signal occurs from an external source (e.g. a ship's log after sailing a specified distance).

After an output, the sequence number is incremented, the ping counter is reset and data collection begins for the next sequence.

Output data will be in biomass per unit surface area or biomass per unit volume depending on the output option selected during entry of parameters (Figure 3).

```
12:27:29 17-FEB-84

INTEGRATOR

2) PRINTER IS ON
3) RS-232 IS OFF
4) LORAN IS ON
5) BOT CTL SCL   0050
6) FILE NUMBER   0003
7) # SEQUENCES    025
8) PINGS/SEQ     0100
9) OUT VOLUME
10) SURFACE LOCK
11) SUFR BLANK 005.0
12) RANGES FOLLOW
 01) D= 010.0 T= 035
     B= 1.000 E 00
 02) D= 020.0 T= 040
     B= 1.000 E 00
 03) D= 030.0 T= 045
     B= 1.000 E 00
 04) D= 050.0 T= 050
     B= 1.000 E 00
 05) D= 100.0 T= 050
     B= 1.000 E 00
13) A CON 1.000 E 00
14) BOT. WINDOW 08.0
15) SBI DIST =  02.0
16) RECORDER IS OFF
```

Loran navigation data (if available) → NO LORAN DATA RCVD

time and date → 15:03:18 17-FEB-84

file #, sequence # and number of pings → F#0003 S#018 P#0100

```
BIOMASS/VOLUME
(01) 1.014 E 02 100%
(02) 1.374 E 03 100%
(03) 1.321 E 04 100%
(04) 1.788 E 04 100%
(05) 1.465 E 04 100%
```

Interval #, integrated values and percentage of interval sampled

special bottom interval → B) 1.228 E 04 100%

sum for all intervals → S) 1.236 E 08

bottom distance and bottom tracking modes used → BT 108.1 AOW

Figure 3. Parameter check printout and integrated output

2.6 Pause and Erase Data

The operator may suspend operation of the echo-integrator by selecting the Pause mode. When the Run mode is re-entered, data collection/processing continues with the sequence which was interrupted when the Pause mode was entered. Data can be erased by entering the Erase Data mode via the Pause mode only. When data are erased, the file number and sequence number remain the same, but the ping counter (or sequence time clock) is reset to zero.

2.7 Inputs and Output Signals

The Model 121 DEI must be synchronized with the echo-sounder to ensure that the echo-sounder output is sampled in the correct time sequence relative to target depth. A sync input accepts a positive or negative going signal of almost any amplitude. Once triggered another trigger will not be accepted for 20 ms, this prevents multiple triggering on noisy or distorted input signals.

The echo-sounder input (or other data) may be a "detected" (rectified) signal or an AC signal. A front panel switch selects the desired data input.

A variety of outputs are provided to simplify monitoring of the system while in operation. The internal threshold voltage (for internal bottom detection) may be monitored and compared to the actual data for threshold adjustments. An interval marker output marks the beginning of each depth interval and the beginning of the bottom window.

There is an output to show the bottom window position and another output to combine the interval markers and the bottom window. The monitor output combines the input data, interval markers, bottom window and bottom detector input so they all can be displayed simultaneously. A 'chart mark' output provides markers at the beginning of each depth interval and at the beginning of the bottom window.

2.8 Remote Bottom Controls

All bottom tracking modes and functions may be selected and performed remotely via a Remote Bottom Control Unit; a useful feature if the monitor oscilloscope cannot be placed near the echo-integrator.

3. DATA LOGGER

The Model DEI may also be operated as a single or dual channel raw data-logger. This mode of operation requires a high speed digital tape recorder to store the large quantities of data rapidly acquired. These raw data can later be analysed or integrated. Possible applications include dual-beam target strength analysis, integration, general acoustic target studies, etc.

Operator entered parameters for the data logger mode of operation include

i. file number,
ii. number of sequences,
iii. number of pings,
iv. date and time,
v. a single threshold dual channel or single channel recording,
vi. maximum depth to which recording will take place.

Input data are sampled with a 12-bit converter at a 7.45 kHz rate (both channels) when the Run mode is entered. If the sample value is below the specified threshold, no recording will take place. When the channel #1 input value exceeds the threshold, the depth is recorded, followed by the sample value for channel #1, then the value for channel #2 (Figure 4). All sample values will be recorded without depth information, as long as the channel #1 signal remains above the threshold. This threshold technique eliminates the recording of noise signals. The bottom depth is recorded along with 10 sub-bottom samples whenever the bottom detect input goes high, otherwise sampling and recording continue until the maximum depth specified is reached.

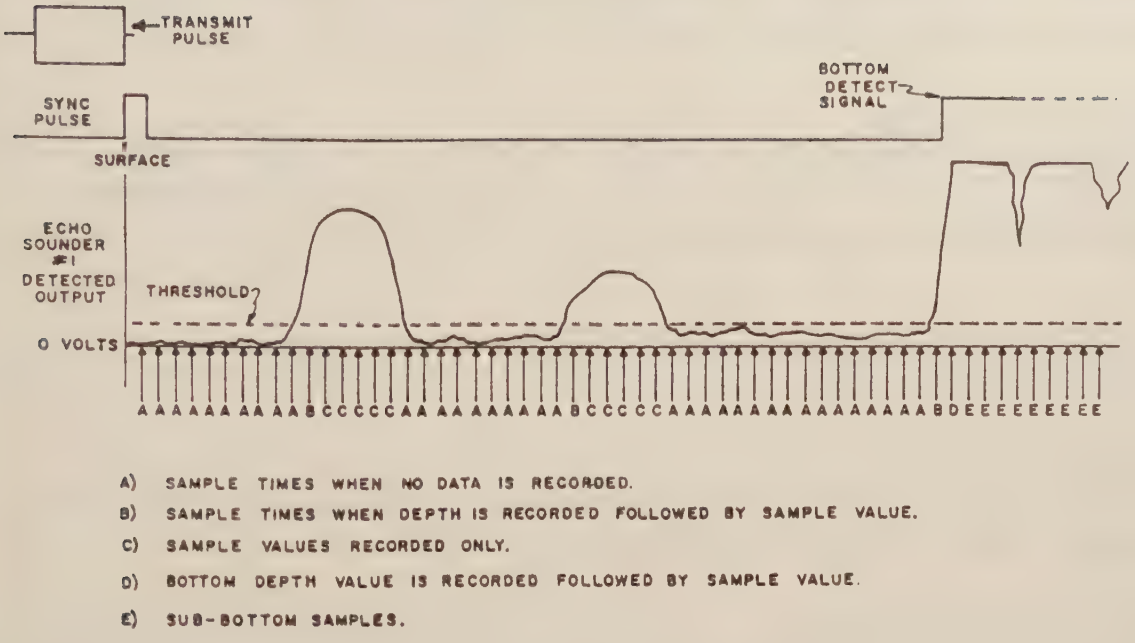


Figure 4. Data logger recording technique

4. SPECIFICATION

4.1 Operator Entered Parameters (via panel keyboard)

Time and Date

Printer on/off

Loran C on/off

Recorder on/off

File number - 0000 to 9999

Number of sequences - 0001 to 9999

Pings per sequence - 0001 to 9999

Time per sequence - 0.1 to 99.9 minutes

Printout type - Biomass per unit surface area or biomass per unit volume

Transmission locked operation or bottom-locked operation

Surface blanking distance - 0.0 to 999.9 metres

Depth intervals - up to 99

- ending distance for each depth interval (999.9 metres maximum depth)
- threshold for each depth interval (0 to 9999 mV)
- "B" constant for each depth interval (.01 to 99)

"A" constant - 0.01×10^{-10} to 99.9×10^{10}

Bottom window width - 0.2 to 20.0 metres

Special bottom interval distance - 0.1 to 10.0 metres

Full scale for manual bottom tracking control - 0.0 to 999.9 metres

4.2 Modes of Operation

Sequential Parameter Entry, Individual Parameter Entry, Parameter Check, Pause, Run, Change Bottom Window, Output, Erase Data, EOF (end of file for tape drive)

4.3 Controls and Switches

On/Off, Reset, AC/Detected (data output), Internal Bot. Det./External Bot. Det., Threshold (for internal bottom detect), Manual Bottom Control, Alarm On/Off, Panel/Remote (for bottom controls)

4.4 Inputs

Detected Signal, AC Signal, Sync, Bottom Detect, Output Command, Loran C, (RS232)

4.5 Outputs

Threshold Monitor, Interval Marker, Bottom Window, Monitor, Chart Mark, Sequence Complete, RS232 (for data output to computer)

4.6 Panel Input/Output Devices

Printer (20 column alpha-numeric), 16 character alpha-numeric display, 16 position keyboard, alarm

4.7 Data Collection

Sampling rate - 7.45 kHz (0.1 metre increments)
Sampling accuracy - 12 bit ADC, 10.24 V full scale

Power

115 VAC or 220-240 VAC, 50 or 60 Hz, 75 Watts (85 Watts when printing)

Size

23 x 43 x 40.5 cm deep (19 x 17 x 16 in deep) not including rack mount handles

Weight

15 kg (33 lb)

Data Logger Specifications:

Operator Entered Parameters
Time and Date
File number - 0000 to 9999
Number of sequences - 0001 to 9999
Number of pings per sequence - 0001 to 9999
Threshold - 0 to 9999 mV
Single or dual beam channel operation
Maximum depth - 0 to 1000 metres

Data Collection

Sampling rate: 7.45 kHz each channel (0.1 metre increments)

Sampling accuracy: 12 bit ADC, 10.24 V full scale range

Notes:

1. The data logging mode of operation requires an additional high speed tape drive and buffered formatter.
2. All operator entered parameters are permanently retained in memory even through power down/power up.

SIMRAD QD ECHO-INTEGRATOR

by

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The method of integrating echoes from fish has been in use since the 1960s, it is acknowledged as a quick and reliable method for fish stock assessment. Until 1980 the SIMRAD QM Analog Echo-Integrator, integrating fish echoes from two selectable depth layers, was the "standard" instrument for this purpose. In developing the new QD Digital Echo-Integrator (see Figure 1), advantage has been taken of the latest available technology in order to obtain a versatile instrument to serve the marine scientists responsible for fish stock assessment.

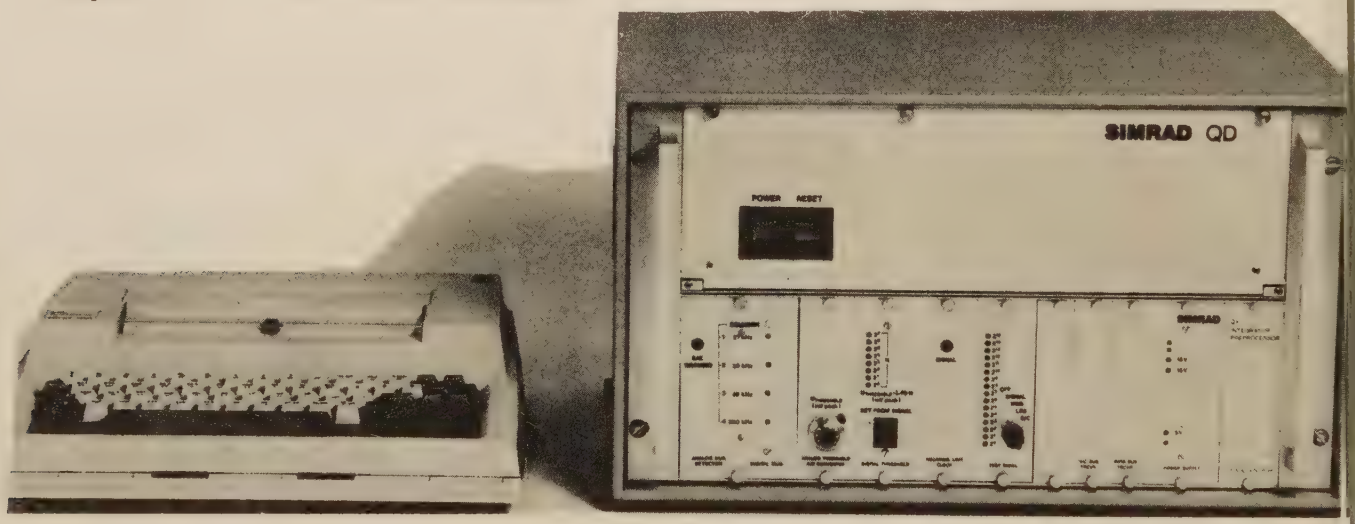

Figure 1

The QD echo-integrator is used for quantification of the biomass in up to 10 different layers of the sea, 8 layers are referred to the surface and 2 layers are referred to the seabed. Results are presented as "Mean Volume Backscattering Strength" for each layer, at each log-interval. This factor (MVBS) can then be used for calculation of tonnes of fish per unit volume or unit surface of sea. The QD has its own data terminal for man/machine communication and data presentation, and a separate data-logger output for interfacing to a main computer or data logger. Besides the fisheries application the QD can also be used to monitor marine pollution in cases where the pollution can be detected acoustically using an echo-sounder.

Compared to the analog integrator, the QD has many advantages:

- Integration of echoes from up to 10 pre-selectable depth layers, 8 of these are referred to the surface, 2 layers are referred to the bottom.
- The mean volume backscattering strength ($\bar{S}_v$) is presented for each of the selected depth layers. Knowing the relation between S_v and the fish density, the total

amount of fish within the depth layer can be calculated. In addition the corresponding mm deflection is presented making it easy to compare the results with data from the old system. An example of the printout from the data terminal is shown in Figure 2 below.

```
VESSEL:                                                        PAGE  2

PLACE:                                                         DATE: ..
COMMENTS:

-------------------------------------------------------------------------
SOUNDER NO.:          2        FREQUENCY:     38.0 KHZ   SOURCE LEVEL:     124.2 DB
PULSE DURATION:    1.10 MS     TRANSDUCER 1  -17.5 DB    VOLTAGE RESPONSE:   3.5 DB
PULSE REP.FREQ.:     50 P/M    TVG:           24.5 DB    GAIN:             -20.0 DB
MAX.RANGE:          884 M      SV-BUFFER:.:  -100 DB     C-ECHO.SOUNDER:   -45.4 DB
-------------------------------------------------------------------------
LAYER NO.      I     II    III     IV      V      VI     VII   VIII     IX
UPPER-LIM     10     85    100    150    200    250                B+ 11.5B+  1.5
LOWER-LIM     85    100    150    200    250                       B+  1.5B+  0.5
THRES.MVP     10     10     35     10     10     10     10     10
REC.CH.                     1                                          2
REC.SCALE                10.00                                    20.00
-------------------------------------------------------------------------

   LOG
  2.0   46.55   0.15   1.20   4.29>>>>>>>>>>>>>>>>                  2.00   1.96
        -49.4  -67.5  -63.5  -57.8>>>>>>>>>>>>>>>>                -54.3  -44.4
```

Figure 2. QD printout

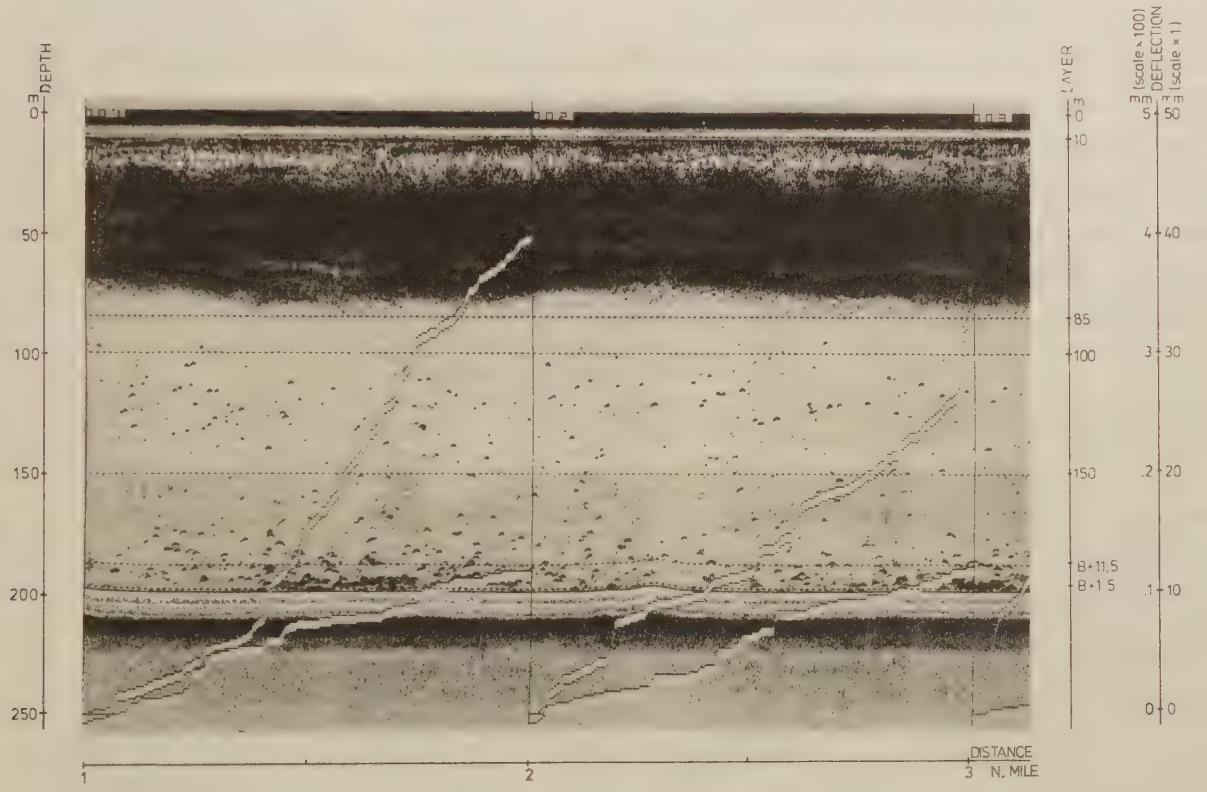

Figure 3. EK400 echo-gram corresponding to printout of Figure 2 above

- The mm deflection of any two of the ten depth layers can be pre-scaled for display on the echo-sounder recorder for easy "judging" of which echo signals have contributed to the total integrated values. Figure 3 shows the echogram (from the EK400 scientific echo-sounder) corresponding to the printout in Fig. 2.
- Large dynamic range: The QD can process input signal levels from -50 dB//1 volt to +20 dB//1 volt without adjusting any gain settings.

- "Window" on bottom pulse assures correct operation of the two layers referred to bottom even if up to three bottom pulses are missing.
- Provision is made for data logging by additional data output.
- Signal input can be selected from up to four different echo-sounders.
- Threshold levels, determining the minimum signal level to be integrated, can be set individually for the chosen depth layers. A control signal from the QD to the echo-sounder inhibits the recording of signals below the chosen threshold level.

In order to take advantage of the high vertical (range) resolution possible with high frequency echo-sounders and short transmitting pulses, the QD measures the echo signal at a very high sampling rate. A measurement is taken every 33 µs corresponding to measurements for every 2.5 cm depth interval. With many calculations needed on every measurement, this high rate requires ultra-fast signal processing and to achieve this, SIMRAD developed a special signal preprocessor, the QX, which is included in the QD equipment.

To make the output of the QD proportional to the amount of fish sampled in the beam, the echo signal voltages have to be squared. The QX preprocessor performs the signal squaring, and to give an idea of how fast this operation is done, a multiplication like 3597x3597 is performed in 0.2 µs (5 million multiplications per second). After the pre-processing in the QX, the signals are further processed by means of two microprocessors, see block diagram Fig. 4, programmed to calculate the $\bar{S}_v$ and the mm deflection values for each depth layer and to present the results as shown in Figs 2 and 3. The QX Integrator Preprocessor can be delivered as a separate unit for those who wish to process echo signals by means of their own computer system.

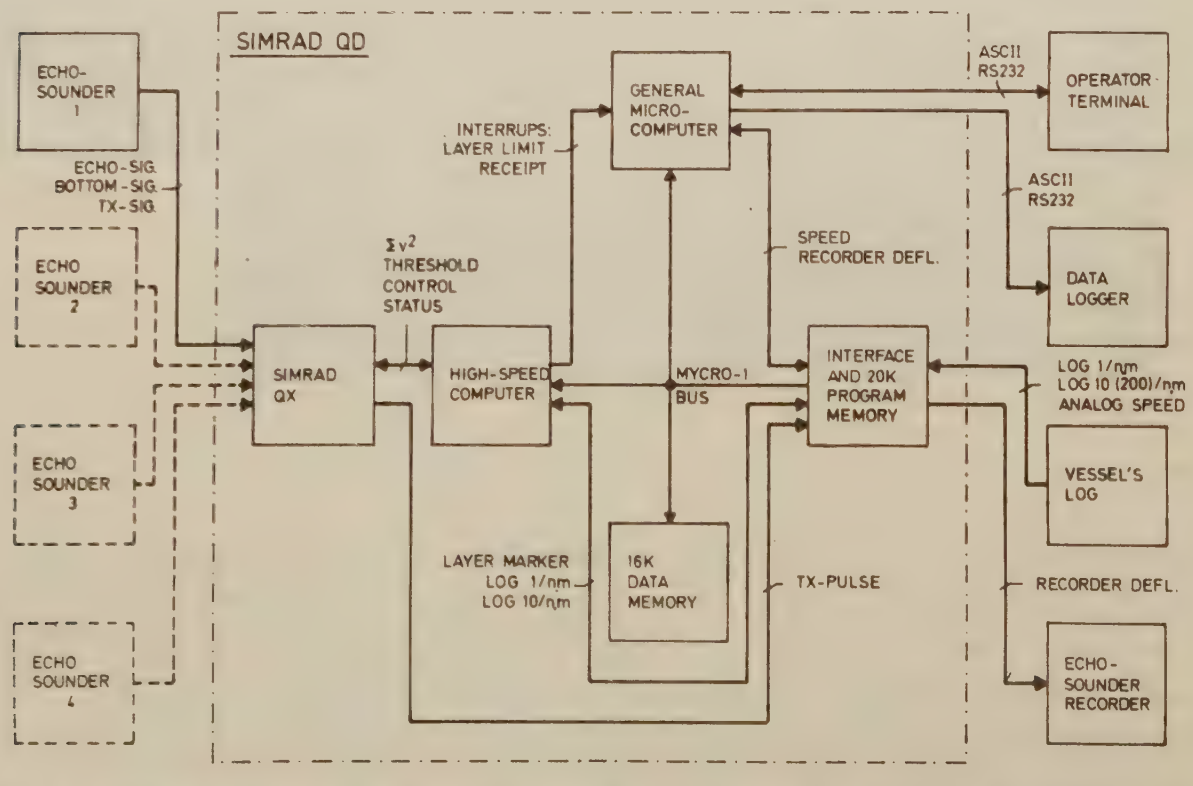

Figure 4 Block schematic for the Simrad QD and connection to external equipment

APPENDIX I

QD ECHO-INTEGRATOR

Technical Specifications

1. GENERAL

The Simrad QD interfaces to EK-400, EK-S and EY-M. The system consists of the Simrad QX integrator Preprocessor and two microcomputers programmed to measure, present and log the mean volume backscattering strength and mm deflection. See System Block Diagram.

2. OPERATING CONDITIONS

2.1 Supply Voltage
230/115 volts AC, 50/60 Hz ± 10%.
Power consumption: Approx. 150 watts.
2.2 Temperature range: 0 to +40°C.

3. INPUTS

3.1 Echo-sounder
Echo-sounder inputs: 4 freely selectable inputs.

Echo signal:	-50 to 20 dB//1 V, 10 to 200 kHz. Input impedance: 2000 ohms//330 pF.
Trigger pulse:	From echo-sounder transmitter.
Bottom pulse:	From echo-sounder bottom detector.
Common for trigger and bottom pulse:	Accepts voltages between 0 to 40 V. Threshold approx. 7 V. Pos. or neg. logic selectable.

3.2 Vessel log inputs
Analog speed: 0 to 10 volts.
Switches for selecting: 0 to 25.5 knots
0 to 16 knots
0 to 12.5 knots.
8 Bits resolution in internal A/D. The speed may also be set manually.

1 pulse per nautical mile:	Startpulse for QD integration.
10/200 pulses per nautical mile:	10 or 200 p.p.n.m. input is switch selectable.
Commons for log pulses:	Active low.

3.3 Operator terminal input

Serial asynchronous interface:	RS 232C
Switch selectable baudrate:	110,300,600,1200,2400,4800,9600,19200 baud.
Switch selectable parity:	No parity or even parity.
Switch selectable bits per character:	7 or 8 bits.

3.4 Only for EK-400 echo-sounder input

Serial asynchronous interface:	20 mA current loop
Baudrate:	1200 baud
Parity:	even
Bits per character:	7 bits.

For automatic updating warning of the following system parameters.
- Gain
- Transmitter pulse duration
- Pulse repetition frequency/Max. range
- Sound velocity
- Transducer change.

4. OUTPUTS

4.1 Output to echo-sounder recorder

Layermarkers:	To display the actual layer picture. May be turned on/off.
Deflection in mm:	Any two of the depth layers. One paperwidth corresponds to 50 mm deflection (compatible to Simrad QM). Scaling from 0.01 to 100. Resolution: 255 levels.

4.2 Data logger output

Serial asynchronous interface:	RS 232C
Baudrate:	300 baud
Parity:	even
Bits per character:	7 bits
Command to change data logger state:	on/off

4.3 Inhibit recorder signal output

Inhibit signal:	Signals below threshold will not be displayed on the echo-sounder recorder.

4.4 Saturation warning output

Saturation:	Input signal > 17 dB//1 V will flash a LED on the front panel and the operator terminal will print a warning.

4.5 Test panel output for performance checking

Status:	Transmitter pulse, Bottom pulse, data ready, Echo-sounder no., overflow, saturation warning, sample code.
Control:	Echo-sounder no. clock, Receipt pulse, Threshold clock.
Signal:	The digital echo signal 12 bits.
MSB:	The most significant bits of the squared and pre-integrated signal.
LSB:	The least significant bits of the squared and pre-integrated signal.

4.6 The digitized echo signal output

Sampling time:	33 µsec
Max. allowable read time:	1 µsec
Echo signal:	12 bits
Other signals available:	Data ready, transmitter pulse, bottom pulse, sample code, sounder no. code, saturation warning.

Complies with EIA standard RS-422.

5. LAYERS SPECIFICATIONS

Sampling of echo signal:	33 µsec (2.5 cm interval)
Resolution in computations:	1 dm
No. of layers referred to the seasurface:	max. 8
Max. depth:	1000 m
No. of layers referred to the bottom:	2 channels
Bottom channel thickness:	0.1 to 100 m
Max. thickness for two bottom layers:	127 m
Bottom offset:	0 to 1 m

Bottom window:
- Depth > 10 m: +25%, -12.5% of detected depth
- Depth < 10 m: ±50% of detected depth
- Open window limits: 1-1000 m
- Max 3 sequential pings outside window before open window.

Threshold levels: Individually to each layer, 8 bits, max. 880 mV peak

The system assumes the sound velocity to be constant: 1500 m/s.

6. CALCULATIONS PERFORMED BY THE SYSTEM

6.1 Mean volume backscattering strength for layer i in decibels:

$$\bar{S}_{V(i)} = 10 \log \left(C_S \frac{\sum_{j=1}^{N} V(j) \cdot Q(i,j)}{D} \right)$$

C_S: constant containing all the topical echo-sounder settings

$V(j)$: vessel speed at ping j

$Q(i,j)$: squared and integrated voltage at ping j inside layer i

$\sum_{j=1}^{N} V(j) \cdot Q(i,j)$: integration over all pings (N) inside a log interval

D: average thickness for layer i over the log interval.

6.2 Deflection in mm for layer i

$$M = C_M \sum_{j=1}^{N} V(j) \cdot Q(i,j)$$

C_M: Constant for deflection measurements

$\sum_{j=1}^{N} V(j) \cdot Q(i,j)$: same as above (6.1)

7. COMMAND SUMMARY

Following groups of commands are available for alternating system parameters.
- Text for survey identification
- Choice of echo-sounder
- Constructing of layer picture/threshold
- Automatic/manual vessel speed selection
- Distance/log-interval definition
- Adjusting of sounder variables
- Listing of system parameters
- Terminal/Echo-sounder recorder output formatting
- Start/stop of system.

All of the commands, except for layer picture construction and choice of sounder, are available for immediately updating of parameters when the system is integrating.

8. AUTOMATIC MEASUREMENTS MADE BY THE SYSTEM

8.1 Measuring of the time between transmit pulses and computation of:
Pulse Repetition Frequency,
Max. allowable range.

8.2 Measuring of the transmitter pulse duration.

9. MAIN HARDWARE/SOFTWARE CHARACTERISTICS

9.1 The system is built up around two microcomputers

9.2 Software is written in high level language

9.3 Total program size: 28k Bytes

9.4 Total data size: 16k Bytes

10. DIMENSIONS

Rack option: Weight: 15.6 kg
Standard 19" rack mounting
Height of front panel 10 9/16" (6 rack units)
Desk option: Weight: 25.8 kg
HxWxD = 29.8 x 50.4 z 40.0 cm

DIFFERENCES IN THE SCALING OF ECHO-INTEGRATOR SURVEY RESULTS BY FISHERIES RESEARCH INSTITUTES

by

John D.R. Bayona
FAO/André Mayer Research Fellow 1/

1. INTRODUCTION

During the last two decades, the abundance of exploited and unexploited fish stocks has been acoustically estimated, mainly by echo-integration, taking advantage of the rapid growth in acoustic technology and instrumentation. This assessment technique has shown promise in establishing indices of fish abundance, particularly, for the following situations:

a. a fishery which has been closed for some time, leading to the lack of catch and effort data
b. a case where catch and effort are mis-reported
c. where the stock, distributed over a wide geographical area, is to be rapidly assessed for evaluation of the investment criteria
d. a stock which becomes suddenly available for assessment within a few hours or days, especially spawning stocks
e. species with a short life span, a case where series of catch and effort data are difficult to obtain for virtual population analysis (VPA)
f. assessment of the recruiting component to stocks.

The principle which governs the routine generation of integrator-abundance estimates is that the energy of echo signals emanating from biological scatterers is proportional to the density of the scatterers. Therefore, fish density is yielded by prior estimation of the proportionality between density and the integrator output (the average sum of echo intensity). Often the proportionality constant is referred to as the biomass scaling constant; it depends on instrument parameters and fish scattering properties. Estimation of the constant, however, varies in approach among institutes. An insight of the differences can be gained by comparative evaluation of the different avenues reported by Dragesund et al. (1973), Thorne et al. (1971), Thorne (1977), Midttun & Nakken (1977), Nakken & Dommasnes (1975), Nunnallee & Mathisen (1972), Johannesson & Losse (1977), Nunnallee (1980), Traynor & Nelson (1981), and Stepnowski & Burczynski (1981). Whilst both biomass scaling and sampling designs are pursued differently, an attempt to establish a standard method for acoustic assessment has yet to be made.

It is the objective of this paper to review the major scaling methods of integrator-abundance estimates and thereby identify relevant differences in approach. Some aspects of the sampling design are also highlighted and it is envisaged that such considerations will all but provide the basis for standardization of procedures and the near-future establishment of a standard method for acoustic assessment. Research information procured from the Institute of Marine Research in Bergen, Marine Laboratory, Aberdeen, Fisheries Laboratory, Lowestoft, UN/FAO projects, University of Washington and the National Marine Fisheries Service in Seattle is of particular assistance to this discussion.

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2. SCALING METHODS AND THEIR LIMITATIONS

The output of an integrator is simply the total echo intensity (I) in an integration depth interval (R_1-R_2) for a certain number of transmissions (P). Since integrators deal with echo voltages, taking n voltage samples per transmission, the output is expressed as:

$$M_I = \left[\left(\sum_{i=1}^{P} \sum_{j=1}^{n} V^2ij\right)/Pn\right] \quad (1)$$

where: V^2ij = squared voltage of the sample

M_I = the output similar to M (M_I is used for digital integration whereas M applies to analog integration)

Fish density (ρ) is derived from the relationship:

$$\rho = C \cdot M_I$$

which expresses the proportionality between fish density and echo intensity. C is the proportionality constant or biomass scaling factor which is determined from a direct empirical approach, or from indirect techniques of system performance measurements.

2.1 Direct empirical approach for biomass scaling

Empirical methods under which integrators are directly calibrated to generate absolute estimates of fish abundance include: cage-confined fish experiments, trawl catches, fish counts and intership calibration.

2.1.1 Cage-confined Fish Experiments

The method was developed by Jóhannesson and Robles (1973 in Margetts ed. 1977) and its application has been demonstrated, particularly in FAO projects. This includes the assessment of nekton biomass of Lake Tanganyika (Jóhannesson, 1975); monitoring of Peruvian anchovy (Jóhannesson & Robles, 1977); estimating of pelagic species in Turkish-waters (Jóhannesson & Losse, 1977), and sardine as well as trumpet fish of Morocco (Burczynski et al. 1982) etc.

A known number of fish (N) of an average weight ($\bar{w}$) g are placed in the cage and acoustically insonified for a stipulated time interval, over the elementary sampling distance unit (ESDU). C is estimated from the expression:

$$C = \frac{3.43\ N\ \bar{w}\ \Delta R}{M\ V} \text{ tonnes/n.m}^2 \quad (3)$$

this formula applies to both analog and digital integrators, i.e. M_I can be used.

where: $\Delta R = R_2 - R_1$, vertical extension of fish in the cage

V = effective sampling volume determined by cage measurements

3.43 = a conversion constant from g/m^2 to tonnes/n.m^2

n.m = nautical mile.

Equation 3 is derived from the integration algorithm described in Forbes & Nakken (1972). The method assumes that fish of nearly the same size are randomly distributed in the cage as they are encountered under survey conditions. It also assumes that the tilt angle distribution within the cage is the same as for the fish in a survey situation and the time varied gain (TVG) remains constant. There must be no changes in either the system source level or receiving sensitivity under experimental and survey conditions.

This direct approach provides the means to bypass problems of estimating the effective sampling volume and fish scattering cross-section. However there are mainly four uncertainties in this approach

a. caged fish are acoustically insonified at a fixed depth, precluding the depth dependent effects on fish scattering
b. the effect of cage confinement on fish tilt angle distribution is often neglected, but so is the extent to which the tilt angle distribution of encaged fish conpares to those beneath a surveying vessel
c. the effective sampling beam angle, assumed in this case to be the basis for establishing the effective volume by cage measurement, may change depending on certain characteristics of target registration.

Forbes et al. (1982) reported that tilt angle distributions of encaged fish seem to depend on the degree of confinement; Nakken & Olsen (1977) demonstrated the dependency of fish echo energy on tilt angle. This explicitly discredits direct estimation of C, based on caged fish. However, simultaneous measurements of target strength and tilt angle distribution of caged fish provides an avenue for assessment of average target strength at expected tilt angle distribution for wild fish at sea. The experiment by Foote (1982) is an improvement to this approach; however, application of average target strength functions, obtained in this manner or other indirect techniques, for computation of C-values calls for additional information on fish behaviour of wild stocks (spatial and orientational distributions as well as avoidance reactions to survey vessels).

2.1.2 Trawl catches

The use of trawl catches for calibration of integrators is an approach which establishes the linearity between density estimates calculated from trawl catches and the corresponding integrator output obtained in the fishing depth. On the assumption that the same linearity is maintained during experimental and actual survey conditions, biomass can be scaled into absolute estimates of abundance.

In Seattle, some attempts to estimate abundance of Pacific herring and hake were based on this approach (Thorne 1971 & 1977). In Bergen a vertification of some results is cited by Strømme et al. (1982). Thorne (1977) established the relationship between trawl catch (C_w per m^3) and integration rate per metre by linear regression analysis, with a line passing through the origin, of the form:

$$C_w = \beta I_m \qquad (4)$$

where: C_w = weight of the catch per m^3

β = estimated slope of a line

I_m = Integration rate per metre.

The biomass scaling constant under this approach is an estimate of the slope (β).

For estimation of surface density of fish, trawl catches per ESDU (normally 1 nm) is an integration interval equal to the net mouth are initially transformed to empirical estimates of fish density by the relationship:

$$\rho_a = 3.43 \times \frac{C_w}{a} \qquad (5)$$

where: ρ_a = empirical estimate of area surface density (tonnes/n.m^2)

C_w = catch in grammes

a = area swept by the trawl in m^2

3.43 = a constant defined in equation 3.

By simple linear regression, a slope β is obtained between empirical estimates of fish density as an independent variable (x) and corresponding integrator values as a dependent variable (y). Therefore C is estimated as

$$C = (1/\beta) \qquad (6)$$

This approach was applied for the assessment of Chilean hake (Merluccius gayi) by Lillo et al. (1982).

Efficiency of the gear has to be estimated. However, some applications assume 100% gear efficiency, implying that all fish recorded within the area swept by the net opening are caught and retained by the net, the assumption is hardly met. Values of C derived by this approach are often biased due to:

(a) fish avoidance or gear selectivity

(b) unrecorded fish due to loss of fish signals (dead zone effects) yet such fish may have a significant contribution to the catch which leads to over estimation of C in the event of bottom trawling. Note however that dead zone effects are related to the depth resolution of the sounder. If we consider the minimum detectable depth resolution to be half the pulse height ($c\tau/2$) on the acoustic axis, the volume in which fish remain undetected increases with an increase in detection angle away from the acoustic axis, due to beam shape

(c) uncertainties of the volume swept by the net. This is assumed to depend on the aperture between the wings, often ignoring the effect of bridles and ground-warp to the efficiency of the gear.

Strømme et al. (1982) obtained a linear function between trawl catches (tonnes/n.m^2) and integrator abundance estimates (tonnes/n.m^2), with a line through the origin. The authors conclude that bias due to dead zone effects may not be as serious as expected, depending on species type and the sounder used. Thorne (1977) reported high variability in estimates obtained by this approach and considers the non-uniformity in fish distribution to be the major problem. In general this approach is inadequate for

precise quantification since both variables are measured with a substantial degree of error.

2.1.3 Fish Counts

Estimation of C by counting of integrated or recorded fish is pursued under two distinctive approaches:

(a) a case which requires a pre-assessed relationship between fish target strength and fish length

(b) a case where estimation of target strength is bypassed.

Counting techniques also vary among research institutions.

For a layer of fairly dispersed fish those contributing to the integrated values are counted as individual traces on the echogram and M_I or M is recorded over the ESDU. Empirical values of area fish density are obtained by the approximation:

$$\rho_a = N/[(\bar{R}\,\Theta)^2\,\pi\,P] \qquad (7)$$

where: $\bar{R}$ = mean depth of counted fish

Θ = effective sampling beam angle

N = counts of individual fish.

This technique was developed for applications by Norwegian researchers (Midttun & Nakken, 1971 and 1977).

Fish counting as practised in Seattle uses CRT-oscilloscope techniques. The number of fish appearing above an established threshold are counted and recorded for each depth strata. This is preceded by estimation of the effective sampling volume for each depth domain. Since the shape of an acoustic beam is analogous to that of a cone, cone radii in each depth slice have to be established as vital parameters upon which pertinent volumes are computed. By assuming that the consecutive number of insonifications for a given fish passing through the acoustic beam is proportional to the region of detectability, the path of a fish can be represented by a chord of a circle whose expectation yields the expression: $(\pi r/2)$. Based on Nunnallee & Mathisen, (1972), Mathisen *et al.* (1977) and Nunnallee (1973), cone radius can be calculated from a well developed expression of the form:

$$\frac{\pi r}{2} = \frac{\text{Boat speed (m/s) x Mean Insonifications (per fish)}}{\text{Pulsing rate (P/s)}} \qquad (8)$$

This case requires overlapping transmissions. Fish density in each depth domain (ρ_D) is obtained by dividing the number of fish counts to the estimated effective sampling volume which, in turn, is initially derived from the expression governing volume measurement of cylinders and for which cone radius is a pre-requisite.

Under FAO projects counting techniques tend to vary; however, Johannesson & Losse (1977) reported the use of an electronic counter, connected to the integrator output, for counting fish above threshold. The effective sampling volume was established by an

approach similar to that of Midttun & Nakken (1971 & 1977). However, some differences between the described Norwegian and FAO approaches lie in the estimation of Θ. To some extent, the parameter is dependent on the distribution of echo strength or simply target strength. By a method of Craig and Forbes (see Forbes & Nakken 1972) a target strength histogram was made (Johannesson & Losse, 1977). Hence the average detection angle Θ was calculated from an observed target strength distribution. In contrast, the reported Norwegian approach established Θ as the angle corresponding to the difference between gain setting on a counting run and the setting when a just visible mark appeared on the echogram. This method will often give a maximum value of Θ.

No sooner is the counting task accomplished by any of the described approaches than the ultimate scaling process begins. For estimation of surface-area density, a line is set between counts (N_i) and corresponding integrator output (I_i) by a method of least squares analysis, in the form

$$N_i = \alpha + \beta I_i \tag{9}$$

Therefore, a scaling constant is obtained by dividing an estimate of the slope (β) to the effective sampling area as below

$$C = \beta/[(\bar{R}\cdot\Theta)^2\cdot\pi\cdot P] \text{ fish/m}^2\text{/mm, per nautical mile} \tag{10}$$

This scaling approach is used in non-overlapping pulse transmissions and it is one among others, implemented by FAO for estimation of absolute abundance of the pelagic fishes in the southern Black Sea (Johannesson & Losse, 1977). Whilst it is imperative to estimate the effective sampling angle Θ under this approach, the problem is bypassed in the methodology pursued by institutions in Seattle. The Seattle approach also partitions fish density per depth strata for further transformation into estimates of surface density. Empirical density estimates from the described counting technique (Seattle approach) and respective integrated values are fitted with a line by simple linear regression of the form:

$$\rho_{Di} = \alpha_i + \beta_{Di} I_{Di} \tag{11}$$

where: ρ_{Di} = empirical density estimates in i^{th} depth strata
α_i = intercept, conceived as threshold density
β_{Di} = an estimate of the slope in i^{th} depth strata
I_{Di} = Integrator output in i^{th}depth strata.

Therefore, C for each depth domain corresponds to the estimated slope (β_{Di}).

A verification of this approach is cited by Nunnallee (1982) who compared acoustic abundance estimates with direct weir counters (down stream migrants) of juvenile sockeye salmon (Oncorhynchus nerka) in Cultus lake. The approach proved capable of providing accurate estimates of abundance, based on the close agreement between acoustic and weir

estimates. A genuine and somewhat negligible difference between weir and acoustic estimates was 2.5%. In practice, the difficult part of this approach is to establish the effective beam radius. Bias in the estimate of beam radius is directly related to boat speed and stratification of fish by size. Pulse rate and depth of fish, however, are indirect causes of bias (Nunnallee, 1980). When fish signals are recorded on magnetic tapes for further analysis the use of a high signal to noise ratio is recommended to mitigate probable biases of saturation as well as counting and integrator thresholds.

The Norwegian direct empirical approach for estimation of C calls for the relationship between the species target strength and length as one of the pre-requisities. C is therefore expressed as a target strength length dependent constant in addition to its dependency on system parameters. The ultimate expression for C is as derived by Nakken (1975)

$$C = C_s C_I \cdot L^{-m} \tag{12}$$

where: C_s = a constant for a particular species
C_I = a constant for instrument parameters
L = fish length (normally the mean is used).

At this stage it is better to consider whether equation 12 can also provide values of C by an indirect approach of system performance measurements as this will be brought up in subsequent discussions. Fish densities, estimated by equation 7 and corresponding integrator values are fitted by least squares analysis to establish a numerical value of C and a threshold density. The parameter m might be estimated from other experiments (target strength to length regressions). Then $C_s C_I$ is obtained from equation 12 if L is known. The parameter L is the mean length of fish which contributed to integrated values during counting runs; it may be estimated from trawl samples.

For survey purposes it is assumed that $C_s C_I$ remains constant for a particular species; hence appropriate values of the scaling constants (C_i) are derived from equation 12 by keeping L as a variable parameter in accordance to actual size (mean length) of free-swimming fish as real contributors to the integrator output. Information on this is recovered from trawl samples.

Application of this approach to abundance estimation of Barents Sea capelin is described by Nakken & Dommasnes (1975 & 1977). Fish density for i^{th} category, normally age/size group, is expressed as:

$$\rho_i = [K_i/(\Sigma\ k_i\ C_i^{-1})]M \tag{13}$$

where: k_i = fraction of i^{th} category in trawl catch
$C_i = C_s C_I \cdot L_i^{-m}$ (equation 12)
L_i = mean length of the i^{th} category of fish
nc = number of categories.

Apparently it is assumed that the contribution of each age/length category to integrated values is reflected by respective catch proportions in trawl samples. Experience, however, has revealed that often 0 and 1 age groups of capelin are under-estimated due to gear selectivity and their distribution near dead zones or boundaries (Nakken & Dommasnes, 1977- Dommasnes 1982). This invalidates the assumption that trawl catches reflect true or representative density ratios of length/age categories of the species being acoustically measured. also $C_s C_I$ does not remain constant under successive surveys; its assessment prior to undertaking any survey is imperative. In general, the approach is not reliable in multispecies situations because of the difficulty in apportioning integrator values among the different species of each contributors.

2.1.4 Inter-Ship Calibration

Some research institutes are involved in acoustic assessment of specific marine stocks which are distributed over enormous areas. Often, limitations in both ship time and operating costs result in inadequate coverage and hence stock under-estimation. Alternatively, if circumstances allow enough coverage, abundance estimates obtained in single ship surveys can be biased because of stock migration, fishing, and natural mortalities. One solution to this problem is to launch a multi-ship survey under which each ship is assigned to cover specific portions of the total survey area. This calls for inter-ship calibration as either the basis for expressing estimates of one ship in terms of the other, or the criterion upon which the acquired estimates can be compared. Satisfactory applications of this approach are reported by Norwegian and FAO researchers (Røttingen, 1978 & 1982; Burczynski, 1979; Elminowicz et al. 1982). (Eureka, Villenuava)).

Estimation of C for one vessel relative to the other can be accomplished by each vessel integrating the echo from a standard target (metal sphere) as a reference target for a simulated time interval over the ESDU. One has to take into account the differences between Ψ of the ships transducers. Also, C can be established by integrating over a fairly homogenous scattering layer of fish. Assuming that ship A is well calibrated and a biomass scaling constant is determined as C_A, the constant C_B for ship B can be obtained from the expression

$$(C_B/C_A) = (M_{IA}/M_{IB}) \tag{14}$$

where: M_{IA} and M_{IB} are integrated values or outputs for ship A and ship B respectively; they are obtained from acoustic deployment on similar targets and in similar experiments. It follows therefore that C_b can be calculated from known parameters as:

$$C_B = (M_{IA}/M_{IB})C_A \tag{15}$$

In situations where the M_I values of one ship are to be transformed or expressed in terms of the other, a transformation constant can be sorted by means of regression analysis between data set series for the two vessels. An appropriate expression is of the

form:

$$M_{IB} = \alpha + \beta M_{IA} \tag{16}$$

It should be noted that there will be biases in estimation of C by this approach. These are often relative depending on errors in

(a) establishing C of the partner vessel,

(b) integrator values which are not recorded exactly from the same fish targets, and

(c) measurement of signals from reference spheres which move relative to the acoustic axis.

2.2 Indirect Approach of System Performance Measurement

This approach is based on the measurement of instrument parameters and average target strength for the species of interest. There are, however, some differences between Institutes in this separation of parameters in equations for generating C. Also, different functional forms of target strength are used. This prompts considerations of both the separation of parameters in equations generating C and the application of target strength functions.

2.2.1 Parameter Separation and Estimation

In Seattle, estimates of volume density are obtained initially for extrapolation to area density estimates. For each depth stratum, volume density is obtained from the relationship:

$$\rho_v = M_I/A\ B = [A\ B]^{-1}\ M_I \tag{17}$$

A and B are called factors; the former is related to system and fish parameters and the latter is related to one way acoustic spreading losses as well as the two way absorption loss.

From the integration algorithm, A is expressed in the form:

$$A = P_o^2 r_o^2\ E[b^2(\Theta,\psi)]E[\sigma/4\pi]c\tau T_e G_o^2 \tag{18}$$

where: P_o^2 = transmitted pressure level 1 m from the transducer

r_o^2 = receiving sensitivity of the transducer

$E[b^2(\Theta,\psi)]$ = expected beam directivity of the transducer

T_e = effective pulse length

G_o = fixed system gain

$E[\sigma/4\pi]$ = scattering cross section of target

When r_o^2 is incorporated in G_o^2 and measured as the ratio of the fixed gain receiver voltage to received intensity at the transducer face, A can then be expressed in the form (Traynor & Nelson, 1981)

$$A = P_o^2 E[b^2(\Theta,\psi)]\bar{\sigma}(c/4)T_e G^2{}_o \tag{19}$$

G_o^2 is now called the system sensitivity.

This procedure is used to avoid the necessity to measure r_o, a parameter which is difficult to measure accurately. Likewise, B is expressed by the following parameters:

$$B = [I/(R_2-R_1)] \int_{R_1}^{R_2} [G^2_{(R)}/(R^2 \cdot 10^{2\alpha R})]dR \qquad (20)$$

where: $G^2_{(R)}$ is the time varied gain (TVG) referenced to G_o.

The value of B is always unity (equals 1) if the TVG is accurate. In case of TVG anomalies however, different corrected values of B are established, one for each depth domain, in a manner discussed by Ehrenberg (1976) and Traynor & Nelson (1981). Therefore B is a uniform constant value for all depth domains in the absence of TVG anomalies; it is otherwise variable among depth domains whenever anomalies are observed. Based on equation 17, C is represented by the following parameters:

$$C = (A\ B)^{-1} \qquad (21)$$

With both the use of the echo-sounders self generated estimates of in situ target strength and the ease of executing the necessary corrections of TVG anomalies, the approach further utilizes the effective physical pulse length (T_e), another impressive advantage. Pulse length is measured in situ using the relationship which was disucssed by Traynor & Nelson (1981), of the form:

$$T_e = \left(\int_{t_1}^{t_2} V^2_{(t)} dt \right) / V^2_{max} \qquad (22)$$

where: V_{max} = maximum voltage of the pulse

t_1, t_2 = the times when an echo voltage drops below the threshold level

T_e is therefore the actual pulse length for the squared and integrated voltage, eliminating possible biases in the use of a fixed value of selectable pulse duration from the echo-sounder.

Points to note with this approach are: (a) lack of control on targets being measured for evaluation of TS in relation to fish properties or for sizing purpose, (b) the targets have to be resolved independently only for measurements of T_e, an infrequent check which rarely shows changes, (c) the equipment is not necessarily bulky or expensive e.g. BioSonics dual beam echo-sounder and integrator; it might be sensitive to noisy conditions, especially for measurements in depths greater than 200 m. Partly due to the large amount of data that has to be procured, implementation of the approach requires adequate data handling facilities.

Stepnowski & Burczynski (1981) present two different approaches of parameter partitioning in equations for generating C. These equations have been applied for biomass scaling by many institutions, especially under FAO projects. Re-written in different notation, the authors derive C as follows:

$$C = k_1 \cdot 10^{0.1(C_v + V_o - A_g - \overline{TS}_{kg})} \quad (23)$$

where: k_1 = a conversion constant from kg/m^2 to tonnes/n.m^2

C_v = echo-sounder constant

V_o = the average value of input signals to the integrator to give 1 mm integrator deflection at 0 dB gain in a 1 m interval

A_g = gain of the echo-integrator.

Application of equation 23 derives biomass per surface area. The echo-sounder constant C_v is expressed by familiar parameters, notably:

$$C_v = -SL - VR + 20 \log R + 2\alpha R + \Delta TVG - 10 \log\psi - 10 \log(c\tau/2) \quad (24)$$

where: SL = Source level (dB//1μPa ref 1 m)

VR = Voltage response (dB//1V per 1μPa)

$20 \log R + 2\alpha R$ = one way spreading and two way absorption losses (dB)

c = speed of acoustic waves (m/s)

ψ = equivalent beam factor of the transducer (dB).

In a different approach by the same authors the estimation of C simply requires pre-established relationships of the target strength to length and weight to length. If C_v, V_o, and Ag (equation 24) are collectively denoted as instrument parameters ($10 \log C'_I$), a new expression of C can be written in the form:

$$C = k_2 \bar{w} C'_I \, 10^{-0.1(m \log \bar{L} + b)} \quad (25)$$

where: m and b stand for a slope and an intercept respectively in the target strength to length regression; $\bar{w}$ is average weight of an individual fish in grams (g), converting fish numbers into a weight measurement; k_2 is a conversion constant from g/m^2 to tonnes/n.m^2.

In Norway, Barents Sea capelin surveys also yield fish numbers by utilizing a somewhat similar approach of obtaining C'_I and m in equation 25 and applying a combination of equations 12 and 13 to obtain surface area density for separate pertinent age groups.

The problems of parameter partitioning in both equations 23 and 25 are related to the dynamic nature of the active volume of the space directivity diagram of the transducer under different conditions of target registration. The equivalent beam factor in equation 24 is taken with other parameters to obtain a constant C_v for a given echo-sounder. Often this factor is taken as a constant value for a particular transducer, i.e. using the full volume of the space directivity diagram on the assumption that targets are observed sufficiently far out in the beam or simply from the whole hemisphere (Midttun, 1981). Alternatively, the beam factor is applied as a variable integral value, especially for echoes being received from a scattering layer (Lozow & Suomala, 1971). Experimental data by Kalikham & Tesler (1982) indicate the dependence of the active volume of the space directivity on: the nature of targets (individual, multiple or mixed), the system dynamic range or the dynamic range of echo-signals, and the applied

threshold. Therefore the parameter has to be estimated frequently for the conditions in situ rather than applying a constant value for a particular transducer.

Yudanov & Tesler (1982) present a parameter partitioning approach to warrant both the use of active or effective volume of the space directivity and an easy manipulation of the obvious changes. C is expressed in the form:

$$C = \frac{k_2 \bar{w}}{C_e C_a \sigma_o \Omega} \text{ (tonnes/n.m}^2\text{/mm)} \qquad (26)$$

where: C_e and C_a are electric and acoustic calibration constants respectively (refer to the authors publication for computational details), and Ω is the often variable effective volume of the space directivity diagram of the transducer.

2.2.2 Functional Forms of Target Strength for Applications

Target strength is the most crucial parameter for the reliability of acoustic estimates; its estimation calls for knowledge of the species size, behaviour, morphology, physiology, and other extrinsic effects on fish scattering of acoustic energy. The nature of the target strength influencing-variables present considerable problems in the evaluation of accuracy of C-values and the generated abundance estimates at large. Nevertheless, different techniques for deriving acceptable estimates of target strength for field applications are developing, each with some limitations. Therefore, a major source of institutional differences in the estimation of C under this category is partly manifested by applications of the different forms of target strength functions, e.g. applications of: average target strength per kg(TS_{kg}) length dependent, average TS_{kg} length independent, average target strength per individual fish TS_{ind} (size/length dependent), and average TS_{kg} or TS_{ind} obtained by direct in situ techniques.

Some institutes apply average TS_{kg} figures without considering length dependence, for example as reported by Iversen et al. (1981) of the Institute of Marine Research in Bergen, also Stepnowski & Burczynski (1981) and Elminowicz et al. (1982) under FAO projects. The parameter (TS_{kg} independent of length) may bias the results especially when the species of interest exhibit considerable annual variations in their mean weights.

Some examples which apply average TS_{kg} length dependence are reported by Aglen et al. (1981) and Aglen & Ustvedt (1981) of the Institute of Marine Research in Bergen among other institutions. C-values can be established in a manner giving some advantages in the assessment of certain stocks. Such advantages are scrutinized by prior evaluation of the different methods which are used to obtain length dependent estimates of average target strength per kg of fish.

The first method is to convert average target strength to length function of an individual fish to a corresponding estimate per kg. This calls for the species length to weight relationship as a major pre-established pre-requisite. Readers are referred to

the work of Halldorsson & Reynisson (1982) as a relevant example of the conversion which was applied to Icelandic herring.

The second method can be pursued on the assumption that the scattering cross-section of fish is roughly proportional to the square of its length ($\sigma \propto L^2$) as observed for most commercial species (Love, 1971). If weight (w) is assumed proportional to the cube of length, it follows that:

$$\rho/w = \frac{K_\sigma L^2}{K_w L^3} \tag{27}$$

K_σ and K_w are constants, or

$$TS_{kg} = -10 \log L + 10 \log (K_{\sigma/Kw}) \tag{28}$$

$K_w = 10^5 \cdot C_f$ when kg and cm are the applied units.

$C_f = (\bar{w}(g)/L^3_{(cm)}) \times 100$, the Fulton's condition factor.

K_σ should be found from regressions of σ and L (TS_{ind} and log L) based on experimental measurements as those described by Nakken & Olsen (1977). The third method obtains length dependent estimates of TG_{kg} from a direct measurement of encaged fish. These results are strictly representing only a specific (real) length of fish under experimental conditions.

The advantage in applying TS_{kg} to length dependence is that the value of C may easily be corrected for the differences in fish size (mean length) between sub-areas of the total coverage. A good example on the application of this approach is given by Aglen & Østvedt (1981). Area estimates of herring biomass in each 225 nm^2 grid were derived as follows:

$$\rho_B = (0.42/27)\ M\ \bar{L}\ 225 \text{ (tonnes)} \tag{29}$$

The value 0.42 was derived from expression 23, described under the FAO approach, but using the average TS_{kg} to length dependence of -31 dB/kg for a 27 cm herring. Therefore, the fraction (0.42/27) is a length weighted value of C (theoretically the C value of a 1 cm fish) which is easily correctable for different sizes (average length) of fish encountered in individual survey grids.

Applications of C-values developed from encaged fish measurements are reported by Aglen et al. (1981) for Skagerrak herring and cod. The measurements of TS_{kg} of encaged fish for the ultimate goal of biomass scaling rarely permit corrections for tilt angle distribution; however, corrections for the differences in length distribution between sub-areas can be easily made.

In a different application, Iversen et al. (1981) reports the use of both TS_{kg} to length independence (-29 dB) and TS_{kg} to length dependence (-10 logL-25 dB) for scaling the results of sprat surveys in the North Sea. These values agree for a 2.5 cm

sprat, but they differ by 6 dB for a 10 cm sprat.

It is reported that TS_{kg} of certain species, e.g. some gadoids, show an insignificant dependency on species and length (Forbes et al. 1982). Nevertheless, the use of average TS_{kg} to length dependence for quantification is now commonly accepted by most institutes. A unanimous agreement for such applications can be quoted for ICES coordinated surveys of herring (ICES document CM 1982/H:4) among the collaborators, namely: Norwegian, British, Dutch and French. Such practice will eventually bridge the gaps in calibrations at large. In general TS_{kg} of fish as either dependent or independent of length promotes the generation of direct biomass estimates (kg or tonne per area surface or per volume). The approach precludes an intermediate stage of estimating fish numbers for a subsequent conversion to biomass estimates; hence, errors might be introduced if such biomass estimates are to be re-expressed in fish numbers.

Estimates of average $TS_{(ind)}$ expressed as length dependent functions provide means for scaling integrator estimates into fish numbers; in some cases, they permit the generation of fish numbers by age groups. Often, corrections for the expected tilt angle distributions are taken into account as reported by Nakken & Olsen (1977) and Foote (1980b). However, applications of TS functions which are obtained by direct in situ techniques (Ehrenberg, 1982; Midttun, 1982) are more advantageous because they represent the real time aspect, depth, size, and immediate or instantaneous physiological state of the target species.

3. SOME ASPECTS OF THE SAMPLING DESIGN

Vital to abundance estimation, although often neglected, is the evaluation of how good and representative are the estimates. This is inferred by establishing the precision of sample estimates rather than the accuracy which is difficult to estimate because the true population size is never known. One cannot measure the magnitude of sampling biases to evaluate accuracy of the estimate.

Precision of a sample estimate is defined as the dispersion of individual sample observations about the population mean, therefore, it is measured by variance and it relates to the: (a) sample size, (b) computational approach as governed by the selected sampling design, and (c) density distribution of fish and their degree of clumping. Accuracy, however, is related to biases which may be introduced by the manner of selecting samples (sampling). Bazigos (1981), Shotton & Bazigos (1982) give a synoptic review of the potential biases in acoustic estimates. These include: inaccessibility of fish due to dead zone effects (fish swimming in surface waters above the transducer) and those in the near-bottom dead zone, also inshore avoidance of survey vessels, shielding, inadequate coverage of the fish distribution and threshold settings for the exclusion of noise from recordings. Some correction or de-biasing technique should be attempted whenever conditions of the survey are likely to introduce any serious biases (discussed above) in the results. However, the most critical biases which are difficult to detect and rectify during surveys are due to errors in system calibration and the assumed, or measured, target strength.

It follows, therefore, that a sample design should promote or attain a desirable level of both precision and accuracy of estimates. Shotton & Bazigos (1982) give a more elaborate definition of an objective sample design; it is the manner of selecting samples to promote:

(a) the generation of consistent estimates, processing desirable statistical properties and accuracy,

(b) the objective evaluation of precision of the sample estimate, and

(c) the comparison of estimates obtained under different designs.

Partly based on the difference in distribution of different stocks, partly owing to the varying goals which acoustic abundance estimates serve, acoustic survey designs are variable not only between different research institutions but also within institutions. Also, the choice of any particular survey design may depend on the competition for survey vessels, i.e. the allocated ship time. Nevertheless, the variability in designs among stocks and between and within institutions, attests the difficulty of allocating some differences in approaches. The attempt here, is to partition and discuss survey designs under two major categories irrespective of the individual Institute's applications. However, some differences between Institutes in evaluating the precision of acoustic estimates are discussed.

An acoustic sample design is based on line transect sampling not point sampling. Designs of this kind, regardless of their varying levels of complexity or sophistication, can yield samples in only one of the two probable forms; either regular or random samples can be procured. Therefore, designs are grouped under two main categories:

(a) regular and

(b) random line-transect sample designs.

Under regular line-transect sampling, samples are collected from parallel or zigzag tracks of uniform or equidistant spacing. Regular parallel patterns of tracking are common and a few examples include the assessments reported by Johannesson & Robles (1977), Midttun & Nakken (1977) and Aglen (1982) among many others. On the other hand, Johannesson & Losse (1977), Thorne (1977), Nickerson & Dowd (1977), Nunnallee et al. (1982) give good examples of zigzag tracking patterns. Sampling is often systematic, selecting either stratified or non-stratified samples. This approach is simple to implement, but it poses some statistical complications which have to be solved. Successive samples from fixed tracks are serially correlated, provoking the assumptions of randomness and independence.

In contrast to the above sample design, Shotton & Dowd (1975) discuss a less regular but probablistic design where tracks are selected or positioned in a probablistic manner. Pre-stratification is mandatory so that transects are randomly located in each stratum. Hence, the manner of selecting samples is analogous to cluster sampling which is a suitable alternative to simple random sampling. Because institutes derive variance by different methods (normally as governed by the sample design) for the ultimate goal of deducing confidence bounds of the estimate, it is rational to evaluate their differences in terms of the data used and the assumptions made.

The first difference concerns the emphasis accorded to the application of non-independent, serially obtained observations for estimation of variance. Whilst, some institutes ignore the effect of serial correlation others establish corrective coefficients, for example the corrective coefficient reported by Hogg & Craig (1968). Although Saville (1977) reported that serial correlation can be ignored on the basis that there are no serious foreseeable problems, latest experimental observations have indicated the contrary; the cases confirm serious underestimation of variance because observations are serially correlated (Shotton, 1981 & Williamson, 1982). Often, the magnitude of error (under estimation) varies among or with populations.

The second difference concerns the definition of an observation, used for estimation of variance. Some institutes apply per pulse measurements as observations (Moose & Ehrenberg 1971, Ehrenberg & Lytle 1977) so that variance is based on pulse to pulse variation of measurements. Others divide a transect into equal sections so that measurements of respective sections form separate observations, the case of intra-transect variability (Thorne et al. 1971). Unlike the two cases above, the difference in successive measurements is used by some institutes as a single observation in the calculation of variance (Bazigos 1981). This case is also different from that which utilizes the entire transect measurement as a single observation. Bazigos (1976 & 1981) demonstrated the use of pertinent measurements from two adjacent transects to form an observation which may be named the 'collapsed strata observation'. A series of such observations are used to estimate variance.

The above observations are applied for different models and assumptions to generate variance and the ultimate precision as earlier stated. Implicit to a model which applies observations per pulse, is the assumption that fish encountered as a function of time follow a filtered non-homogenous Poisson process; this is only rarely true (Shotton, 1981) and the assumption leads to underestimation of variance. Likewise, variance estimates based on regular spaced transect observations whose autocorrelation is developed to account for their non-independence, suffers from the inadequacy of the model; it assumes that the distribution of fish density, encountered along a given transect conforms to a homogenous Poisson process. Shotton & Dowd (1975) confirmed that fish depict some trends in their successive density distribution; therefore, the assumption of homogenous Poisson process in untenable. The authors also discredit Yates method of mean square successive differences in observations because the derived estimates of variance are often underestimated. Variance estimates based on observations obtained from randomized clusters or transects, however, are acceptable as good estimators of variance (Shotton, 1981; Shotton & Bazigos, 1982, Yudanov & Tester, 1982, Williamson, 1982).

The third difference in approach is related to units of measurement. Observations are based on either fixed time or distance measurements and examples to illustrate such differences are numerous. In Aberdeen, the Marine Laboratory obtains integrator observations after a fixed time interval called a "timeblock"; the fixed lapse in time is often 30 minutes the integrator is then read, reset, and a record made of ship position based on Decca Navigator readings. Hence, there is one estimate of mean fish density (this integrator has three depth channels) per time block, obtained without making use of

travelled distance measurement from the ships log. Most other institutes, however, generate integrator observations after a specified number of transmissions or the distance sailed.

Whilst some institutes estimate the precision of acoustic measurement of a single survey, others judge precision of consistently obtained measurements in subsequent years or by comparison of estimates from surveys repeated within a relatively short time. This is the fourth difference in the practice of institutes for estimating precision. The variability observed by comparing subsequent annual data is a result e.g. of the changes in stock productivity as influenced by some biological factors and the shortcomings in the technique. However, this also permits judgement of accuracy when estimates yielded by other techniques are compared or evaluated together. Comparison based on subsequent annual data are reported by Nakken & Dommasnes (1975 & 1977), Dommasnes (1982), and Nakken & Ulltang (1982) for Barents Sea capelin. Good examples of variance estimates obtained from surveys repeated within short intervals of time are reported by Johannesson & Losse (1977) and Aglen (1982).

4. A DISCUSSION OF THE MAJOR DIFFERENCES

In the earlier presentation of different biomass scaling methods, both direct and indirect, and a discussion on the criteria for selecting samples, it was demonstrated that major differences exist. These are in terms of approach, in the method, instrumentation, fish scattering models, and sample designs.

4.1 Instrumentation

Different designs of echo-sounders and signal processors are available. These differ in terms of transportability, versatility and cost effectiveness, accuracy, stability, reliability and sophistication. A comparative review of some of the latest systems is reported by Bayona (1982). It is reiterated, that the effectiveness of these systems to the assessment problem mainly depends on the users calibration approach. The entire calibration process includes physical measurement of instrument parameters and the contribution of a given biological target to the total received echo energy. This section is addressed to the problem of measuring some of the essential instrument parameters. Measurement of system source level, receiving sensitivity and beam directivity is pursued differently by most institutes and a standardization in the measurement procedures is deemed desirable.

The measurement of source level and receiving sensitivity, as either combined or separate parameters, is in practice obtained by at least four different approaches, depending on the availability of equipment and their convenience to the users. These include use of standard calibrated hydrophones, transducers, spherical targets, and a combination of uncalibrated hydrophones and projectors. Some of the relevant applications are reported by Forbes & Nakken (1972), Blue (1973 & 1982), Foote & MacLennan (1982), Robinson & Hood (1982), Suomala (1978) and MacLennan (1982).

The use of calibrated hydrophones and projectors is not the best approach for measurement of the acoustic parameters because these devices are susceptible to

environment-induced variations in their responses. A 95% confidence interval of ±1.0 dB is often observed for the hydrophone sensitivity (Blue 1982). It excludes calibration errors in measurements of distance and electrical or biological noise. 'Standard transducers' for calibration purposes require special attention to the influence of temperature on the transmitting response of the projector. Therefore, this calibration approach should strictly be limited to the range of operational conditions likely to be encountered in the field; this presents some difficulties in application especially when large changes in temperature are encountered. Blue (1982) reports that this method may yield an interval about the true value of ±1.4 dB with 95% confidence.

A reciprocity technique which utilizes uncalibrated hydrophones and projectors is reported by Robinson & Hood (1982). If properly implemented, it is capable of yielding repeatable calibration accuracies of ±0.5 dB. In a different study of the ad hoc approach, Blue (1982) reports accuracy of 0.3 dB in calibration by conventional reciprocity techniques. These are amongst the most expedient means of calibration although somewhat bulky equipments are required.

Measurements from standard reference targets can be very accurate and the approach is advantageous in many ways. In the past the measurements were highly variable and application of the approach was jeopardized by inadequately characterized targets but this is no longer true. Once the target strength of a sphere is established it is expected to remain constant but it must not be used at frequencies near resonance. The target strength of some of the earlier reference targets, e.g. ping pong or table tennis balls was a major source of variability at some frequencies, not withstanding Welsby & Hudson (1972). As a result, Dunn (1982) concludes that these balls are generally not suitable as universal standard targets, although they may have some applications at certain frequencies, e.g. 30 kHz, but not 38 kHz.

Properly selected spheres have the advantage of stability in target strength with a response independent of rotation and no additional electronic equipment is required as for the preceding calibration methods. To take advantage of this approach, however, choice of the right material and optimization of the spheres is imperative. Suomala (1978) considered the practical use of spherical reference targets for calibration and concluded that spheres should be rigid with a stable surface, the material of which is homogeneous and conforming to standard specifications of elasticity. Researchers in Norway have demonstrated success in their choice of copper spheres as reference targets (Foote et al. 1981 & 1982) and the same has been demonstrated for tungsten carbide (MacLennan, 1981). These spheres are also non-corrodable. Tungsten carbide is comparatively harder than copper but it is commonly available as an off-the-shelf item (precision sizing balls) thus avoiding machining problems.

Optimization of the spheres is well reported by the above authors whose publications can be consulted for details. This includes the latest optimization by Foote & MacLennan (1982) which aimed at having the sphere target strength comparable to that of ping-pong balls (around -41.5 dB). For this optimization, electrical grade copper (30.4 mm in diameter with TS of -40.7 dB) and tungsten carbide (38.1 mm diameter with TS of -42.4 dB) are reported suitable for calibration of 38 kHz sounders.

In general, the approach has been improved such that the calibration of acoustic equipment (combined measurement of source level and receiving sensitivity i.e. SL + SRT) can be accurately effected to within 0.1 dB in theory. The implementation of this calibration demands calm waters in well sheltered places for proper alignment of the target on the acoustic axis and the elimination of interference from noise.

The question of beam directivity was discussed earlier. Although laborious, some of the direct empirical approaches can bypass the problem of estimating the active volume of the space directivity of the transducer. Desirable accuracy can be attained if such approaches are well implemented, depending on the characteristics of the echo-sounder, target distribution, ship speed and other sources of bias as earlier described for the Seattle approach and the investigations by Nunnallee (1980 & 1982). Indirect approaches based on performance measurements are time conserving and easy to implement; however, they require among others the estimation of the effective volume of the beam directivity rather than assuming a full volume or a constant value for a given transducer (see section 2.2.1). Depending on the characteristics of target registration in situ, active volume of the space or beam directivity of the transducer can be estimated reliably and the work by Kalikhman & Tesler (1982) on this demonstrates the possibility of reducing the associated errors to within 10-15%.

4.2 Fish Scattering

Section 2.2.3 discusses the different forms of average target strength for calibration purpose at large. Although no acoustic theory has yet been formulated to fully describe the scattering process from fish in their environment, target strength functions with respect to length and aspect, taking account of behaviour patterns can be used for calibration purpose. The work by Foote (1982), comparing encaged and anaesthetized fish, validates the use of such functions although some of these may be for somewhat crude calibration purposes. Differences in calibration between institutes include the application of

(a) average TS_{ind}-length dependent and are corrected for the expected tilt angle distribution of the wild stocks,

(b) average TS_{kg}-length dependent, obtained by conversion techniques of TS_{ind}-length dependent or by direct estimation with respect to specific size of a target and correcting for the encountered size (length) at sea,

(c) average TS_{kg}-length independent, and (d) average TS_{kg} or TS_{ind} obtained in situ by direct (dual or single beam techniques).

A proportionality constant which generates estimates of density in terms of fish numbers for further conversion to biomass estimates, apparently utilizing average TS_{ind}, is probably the most ideal for precise scaling applications (see 2.2.2). However, application of TS_{kg} to length independence may sometimes results into unreliable or fairly crude results as reported by Yudanov & Tester (1982). This is because such estimates incorporate weight of the fish which to some stocks may be fairly dynamic and as it can be inferred from seasonal or annual changes in the species condition factor. Reference to this is made based on the work of Halldorsson & Reynisson (1982) on Icelandic capelin;

the authors conclude that 'TS_{kg} for capelin is not thought realistic as its mean weights may vary considerably from year to year'.

4.3 Survey Sampling Designs

Different designs are presented in section 3. Likewise, differences in the estimation of precision of sample estimates are discussed.

Observations based on randomized transects or clusters provide good estimates of variance. Random tracks however, may lead to gross errors in estimating biomass when prior information on density distribution is unknown. The issue has been subject to many discussions, including the forum session discussion of the Biomass Technical Group on programme implementation and coordination, held in France during the week 4-6 June 1980.

An investigation on various patterns of density distributions and conditions under which randomization of tracks can in practice yield unbiased results, has yet to be conducted to promote recommendations for standardization of designs. Shotton & Bazigos (1982) and Yudanov & Tesler (1982) confirm that such information is currently non-existant. Experience, however, has revealed that most fish populations are congruous in distribution. In the essence, acoustic data tend to follow a negative binomial distribution; it tends to a log normal distribution as the degree of clumping increases. Despite such distributions, confidence intervals are established and even parametric tests can be conducted by assuming that for large samples, sample means are normally distributed regardless of the distribution in sample observations (Central Limit theorem). The question here is: how large is the sample in order to obtain normal distribution under this theory. Such uncertainties should be addressed in future studies.

5. CONCLUSION AND RECOMMENDATIONS

Acoustics is nearing 20 years of development in its application to fish stock assessment techniques and instrumentation. At this stage, there is a need to evaluate different biomass scaling techniques and sample designs in an attempt to standardize some procedures. Also there is a need to define a standard method for acoustic assessment, i.e. a method which could be considered ideal for some applications. It is recommended therefore that a special working group be established to review and integrate different ideas for the same purpose. Under this proposal, the working group should take note of the following:

5.1 The current practice of biomass scaling varies among research institutes. Direct empirical approaches of biomass scaling (see section 2.1) are generally time consuming; some of these are based on assumptions which in practice are hard to meet. Indirect approaches based on system performance measurements are therefore more favourable because they are time conserving and are systematic in parameter measurements. These can still be improved as robust and expedient means of biomass scaling.

5.2 Implementation of indirect approaches for biomass scaling based on system performance measurement (section 2.2), at the best, should take account of the following:

(i) the use of active or effective volume of the space directivity in respective different characteristics of target registration, the dynamic nature of which may call for a separate partitioning of the parameter in the biomass generating equation.

(ii) the use of the effective pulse length and a parameter for correction of the TVG anomalies to enhance the certainty of the derived estimates.

5.3 Average target strength (TS_{ind}) as derived by direct in situ techniques or in the form of TS to length functions (corrected for tilt angle distribution) can be used for scaling purposes. Applications of TS_{kg} to length independent (section 2.2.2) may bias the results; besides, errors in re-expressing biomass estimates (derived using TS_{kg}) into fish numbers can be avoided if the scaling constant C (based on TS_{ind}) is applied to yield fish numbers for subsequent conversion to biomass. Some improvements in measurements and applications of target strength functions, however, call for further studies on fish behaviour and reactions to research vessels.

5.4 Measurements of system source level and receiving sensitivity can achieve a high degree of accuracy by use of either reciprocity techniques (accuracy within 0.3 dB) or improved standard targets. Precision calibration by choice of optimized copper and tungsten carbide can be effected to within 0.1 dB accuracy. These are recommended for application where conditions permit.

5.5 Different sample designs and pursued yielding different levels of precision and accuracy of the estimates. The non-homogeneity in fish distribution, patterns of distribution, levels of clumping, conditions governing randomization of survey tracks, and the loosely applied yet unvalidated assumptions or theories for the estimation of precision (section 3) preclude immediate recommendations of a standard procedure which is effective for a particular situation of stock distribution. Although stratified cluster sampling with random allocation of tracks is conceptually promising, it is highly recommended that the preceding uncertainties be clarified by experimental data in future studies.

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